New Scientist

WEEKLY 28 December 2024

2025 NEWS PREVIEW

OZEMPIC MAY TREAT ALZHEIMER'S

BLASTING OFF TO THE MOON

CRISPR PIGS GO TO MARKET

A NEW ELEMENT FOR THE PERIODIC TABLE

WILL WE FINALLY UNDERSTAND DARK ENERGY?

SPECIAL ISSUE

UNDER YOUR SKIN

Why healthy skin means a healthier life

How to harness your skin's microbiome

Which skincare ingredients are proven to make a difference?

How your mental health affects your complexion

What are 'tweakments' and do they do any good?

Should you be wearing sunscreen in winter?

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Incredible cosmology

Powerful telescopes and computers are rapidly advancing what we know about the universe. From the nature of dark matter and dark energy to the origins of the universe itself, scientists are tackling big questions that challenge our understanding of reality. On 15 March at London's Congress Centre, join six world-leading experts as they reveal the latest research on our cosmos.

newscientist.com/events

Tour

Total solar eclipse 2027: Egypt

Witness a total solar eclipse from an enviable vantage point on the Nile. Sail from Aswan to Luxor, surrounded by the timeless beauty of Egypt's ancient landmarks, with Egyptologist-led shore visits. On the cruise, there will be talks from eclipse expert Jamie Carter and astronomer Martin Griffiths. This 10-day tour starts on 27 July 2027 and costs from £5699.

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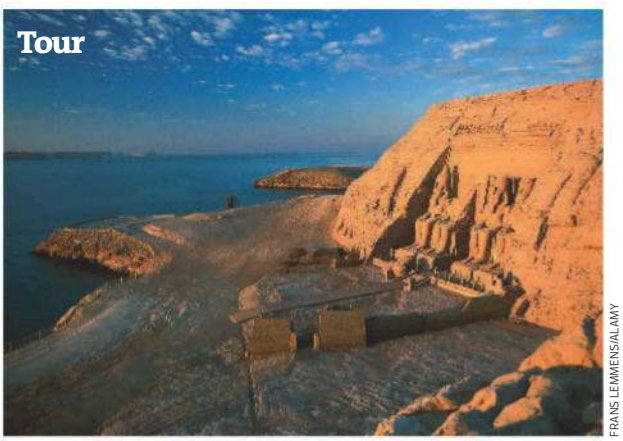
Podcasts

Weekly

The panellists unpack Google's claims that it has pulled ahead in the race to build quantum machines that can beat even the world's best conventional supercomputers. They also discusses how advances in brain imaging and artificial intelligence are revealing ways to keep your brain young.

newscientist.com/nspod



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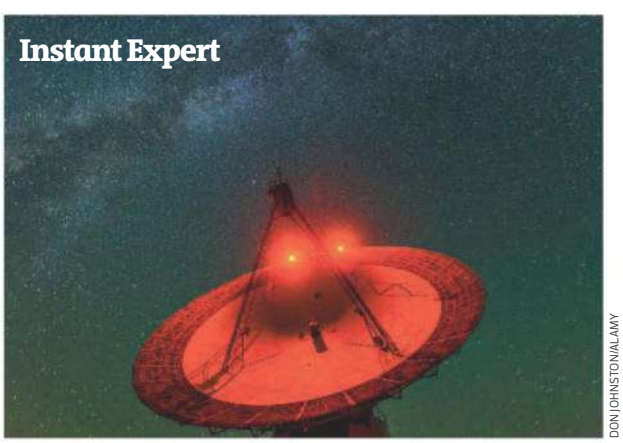
Nile cruise Experience 2027's total solar eclipse in splendour



DON JOHNSTON/ALAMY

Revealing the cosmos What mysteries lie in the depths of space?

Video

Fire in the hole

When a wildfire burns, heat and smoke can alter the chemical composition of water that seeps into caves below. Over millennia, these telltale chemicals build up in subterranean structures known as speleothems, which protrude from every surface where water flows. In Oregon, a team of researchers is studying these deposits to better understand Earth's past.

youtube.com/newscientist

Newsletter

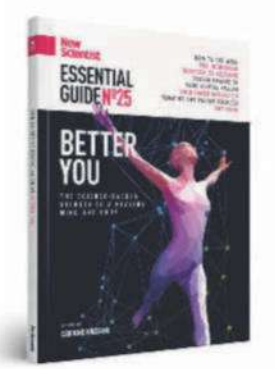
Launchpad

Albert Einstein always seems to be right. That can be frustrating, as it means we haven't detected signs of new physics, but it is impressive that relativity still holds up so well. *New Scientist*'s Leah Crane reports on another Einsteinian "home win" at the Dark Energy Spectroscopic Instrument (DESI) in Arizona.

newscientist.com/launchpad

Podcast

"The idea that quantum computation occurs in parallel universes is lent new credence"



Essential guide

Achieving a state of well-being can feel like a constant struggle. Let science be your guide to better mental and physical health, including recent research on possible ways to slow ageing and the best methods to get fit. Find out more in this 25th *Essential Guide*, available now.

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More than skin deep

Forget aesthetics, the reason to look after our skin should be health

OUR skin isn't just our biggest organ, it is also the one we are most familiar with. We look at it constantly, touch it, wash it, inspect it. And yet, when we think about looking after it, our minds often jump to aesthetics. We are inundated with ads for lotions and potions that promise to enhance our appearance – as if sex appeal is all that matters about this special organ.

There are many other reasons to take care of our complexion besides cosmetic concerns, however. According to new research, its condition can have knock-on effects for the rest of the body. Due to the dense thicket of blood vessels running under the surface, inflammation that starts in the skin can easily spread to the heart and the brain, increasing the risk of cardiovascular disease and dementia, for instance. Wrinkles aren't just a projection of our age – they can actually drive the ageing process. And so we should think of skincare in the same way as exercise: the best reason to do it isn't for looks, but for the undeniable health benefits.

Ensuring our epidermis is in excellent condition should therefore be a priority for anyone who wants to increase the chances of living a long life, which is why we have produced a special report on what we know about the best ways to care for it (see page 28).

"Taking a scientific approach can help us to make informed decisions about new products"

As the evidence builds about the importance of the skin for general health, research into how to care for it is moving away from marketing campaigns for healthcare products into the realm of proper scientific study.

We now know that certain foods can reduce the damage caused by air pollution and the sun's UV rays, for example, and we may be able to nurture its microbiome through more regular contact with nature. Taking a scientific approach can also help us assess new fads and fashions, so that we can make informed decisions about the goods and services with proven benefits, beyond claims of quick fixes.

Beauty may not be skin deep – but there is nothing shallow about wishing to protect our bodies from the outside in. It may save our hides in more ways than one. ▮

PUBLISHING & COMMERCIAL
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Display advertising
Tel +44 (0)203 615 6456
Email displayads@newscientist.com
Sales director Claudia Nicoletti
Account manager Mila Gantcheva

Recruitment advertising
Tel +44 (0)203 615 6458 **Email** nssales@newscientist.com
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Technology

1 Time to take off in style

Flying taxis may finally arrive in 2025, thanks to a new breed of aircraft – electric vertical take-off and landing (eVTOL) models that aren't simply a new spin on helicopters. Rather than relying on one large set of rotor blades for lift, these vehicles use multiple smaller propellers, similar to drones. The propellers face upwards during vertical take-off or landing, but can also tilt forward to enable horizontal flight more like a fixed-wing aircraft – providing greater versatility and efficiency than conventional helicopters.

The first eVTOLs are already rolling off test production lines as air taxi companies such as Joby Aviation (pictured) say they could soon start commercial passenger flights. Joby plans to begin a service in Dubai in the United Arab Emirates as soon as late 2025, with New York City and Los Angeles to follow.

DAVID PAUL MORRIS/BLOOMBERG VIA GETTY IMAGES

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Cosmology

Shedding light on dark energy

A map of 31 million galaxies could reveal the history of a mysterious cosmic force

Karmela Padavic-Callaghan

WE THINK dark energy makes up most of the universe, but we have no idea what it actually is. In 2025, the Dark Energy Spectroscopic Instrument (DESI) in Arizona may offer clues, particularly in relation to how this strange force has changed as the universe matured.

"Either there is some new form of dark energy that we don't know about yet or this could be a paradigm shift, maybe [the data will show] that there is something we don't understand about space and time," says Mustapha Ishak-Boushaki at the University of Texas at Dallas.

"MAYBE THERE IS SOMETHING WE DON'T UNDERSTAND ABOUT SPACE AND TIME"

In March, the DESI researchers will share their analysis of three years of the instrument's data. They will describe how around 31 million galaxies form clusters across the universe and how this cosmic structure has changed in the past 11 billion years, as far as DESI can see. An early look released in April 2024 suggests dark energy, which is thought to be making our universe expand ever faster, may have been stronger in the past.

The idea that dark energy could have changed over time came as a big surprise, says Nathalie Palanque-Delabrouille at Lawrence Berkeley National Laboratory in California. "This really has shaken the community," she says. But these early results couldn't fully rule out the more traditional cosmological model, where dark energy has a constant value, so more data is eagerly awaited, she says.

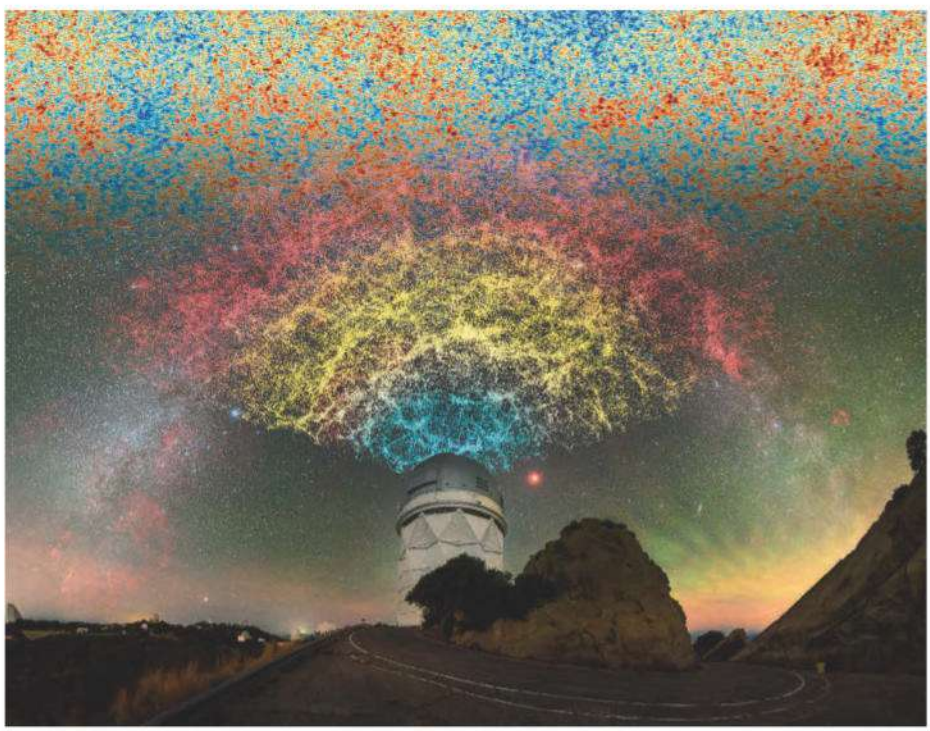
"At this stage, it's more of a hint than it is a discovery," says Itamar Allali at Brown University in Rhode Island. "A lot of researchers said, 'Well, I really would like to see year three data now.'"

The same is true of several other cosmological questions that DESI may be able to address, says Allali. For one, it may show new shifts in the Hubble constant, which measures the rate at which the universe is expanding. The exact value of this number is controversial because different methods of determining it haven't always agreed. Allali and his colleagues have previously suggested that part of the problem may be the presence of yet another mysterious entity, which they named dark radiation.

Previous DESI analyses haven't ruled out this exotic idea, but new data may weigh in more heavily on the issue, especially if the Hubble constant is indeed different to what physicists previously thought, says Allali. "This is super exciting for people like me who want to solve huge cosmological problems."

Another long-standing issue DESI could address is pinpointing the masses of ghostly particles called neutrinos. These barely interact with other particles, but we can still determine their properties by studying the cosmic structure that is being uncovered by DESI. Initial data narrowed the difference between the upper and lower bounds on neutrino mass – it got close to a single number – but Allali says clarity will only come with more data. If DESI can pinpoint the neutrino mass further, it may be the result that "has the broadest impact on all of physics" from the instrument, he says.

For more on dark energy, see page 18



RIGHT: DESI COLLABORATION/KPNO/NOIRLAB; BELOW: MARILYN CHUNG/LBNL, BERKELEY LAB

Above: This rainbow pattern shows the structure of 60,000 galaxies as captured by the Dark Energy Spectroscopic Instrument Below: One of the hundreds of thousands of components that make up DESI

Could Ozempic slow the progression of Alzheimer's?

Grace Wade

OZEMPIC and Wegovy are already transforming how we treat type 2 diabetes and obesity, and from next year another condition affecting millions of people worldwide might be added to the list: Alzheimer's disease.

Two clinical trials investigating semaglutide, the drug in Ozempic and Wegovy, as a therapy for early Alzheimer's are expected to conclude in 2025. If the results are positive, it could mark a breakthrough in treating this intractable condition.

Semaglutide belongs to a class of drugs that mimic a hormone called GLP-1. These GLP-1 agonists, as they are known, have wide-ranging effects, including regulating blood sugar, suppressing appetite and dampening inflammation. A growing body of evidence suggests that they may treat Alzheimer's too.

The most compelling research is a small trial involving 204 people with mild to moderate Alzheimer's. Paul Edison at Imperial College London and his colleagues found that one year of treatment with a daily injection of liraglutide, a GLP-1 agonist that is similar to semaglutide, slowed cognitive decline by 18 per cent compared with a placebo injection. The work, presented at the Alzheimer's Association International Conference in July 2024, also showed the drug reduced brain shrinkage by about 50 per cent in areas vital for memory, learning and decision-making.

In another study published in October, Rong Xu at Case Western Reserve University in Ohio and her colleagues analysed health records from more than 1 million people with type 2 diabetes – which is considered a risk factor for Alzheimer's – and found that those who were only prescribed semaglutide had a 67 per cent lower risk of developing the condition during the three-year study period than those who were only taking insulin.

It isn't entirely clear why GLP-1 agonists appear to slow or even prevent Alzheimer's. It could be through improving metabolic function in the brain, which is the ability of neurons to use glucose for energy, says Suzanne de la Monte at Brown University, Rhode Island. She notes that people with Alzheimer's have impairments to their brain metabolism, which may contribute to their cognitive decline.

Other possible explanations include semaglutide reducing inflammation or improving risk factors associated with Alzheimer's, such as type 2 diabetes, says Xu.

Results from the two later-stage trials that are due to finish at the end of 2025 – as confirmed by a spokesperson for Novo Nordisk, the pharmaceutical firm behind them – should help us uncover these mechanisms. Each includes roughly 1800 people with early Alzheimer's who will have received either a daily tablet of semaglutide or a placebo for three years.

The main difference between the two trials is that in one of them, at least 20 per cent of the participants have small vessel disease, in which blood vessels in the brain narrow or become obstructed. Many people with Alzheimer's also have small vessel disease, so this trial in particular will help us understand how semaglutide affects those who represent the general Alzheimer's population, says Rebecca Edelmayer at the Alzheimer's Association in Chicago, Illinois.

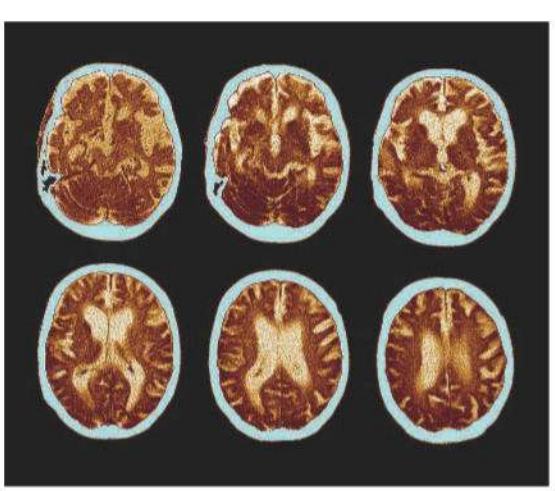
Only two therapies – donanemab and lecanemab, two antibodies that remove sticky amyloid protein plaques from the brain – have ever been shown to slow the progression of Alzheimer's. Yet their effect is modest and their high price, infusion delivery and risk of serious side effects have kept them out of reach for most people with the condition.

If semaglutide is shown to treat Alzheimer's, we probably won't have a use for these antibody drugs, says de la Monte. However, Edelmayer believes that they will remain a treatment option. Some people may respond better to one drug than another, she says. "We want this disease stopped in its tracks, so patients need options."

> "WE WANT THIS DISEASE STOPPED IN ITS TRACKS, SO PATIENTS NEED OPTIONS"

67%
Reduction in risk of Alzheimer's in those taking semaglutide in a three-year trial for type 2 diabetes

2
Number of therapies currently shown to slow the progression of Alzheimer's



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REUTERS/GEORGE FREY

The brain shrinkage observed in Alzheimer's (see scan, left) may be prevented by semaglutide, the drug in Ozempic (above)

Climate change

Will Brazil get COPs back on track?

The host of the next UN climate talks wants to foster a more collaborative approach

Madeleine Cuff

IN NOVEMBER 2025, climate negotiators will descend on the tropical city of Belém in Brazil, gateway to the Amazon rainforest, for the next round of UN climate talks. Despite the exotic location, delegates are unlikely to be in high spirits. The 2024 talks in Baku, Azerbaijan, ended with a fragile agreement on climate financing that left many lower-income nations disappointed and some in open revolt.

For Brazil, the first task as COP30 host will be to calm tempers and smooth tensions after the quarrelsome atmosphere of Baku. It is no mean feat given years of strained relations between wealthier nations and their poorer counterparts.

But Brazil has experience in this field, says Joanna Depledge at the University of Cambridge. In 1992, it hosted the Rio Earth Summit, a landmark meeting that brought countries together to establish the COP (conference of the parties) process under the UN. Brazil has "vast diplomatic and climate change experience and huge credibility in the international community", says Depledge.

More collaboration will be desperately needed at the summit if the world is to avoid runaway climate change. Countries have until February to submit new climate plans to the UN, detailing how they will cut emissions from now to 2035. The hope is that the new plans will help to close the gap between the goals of the Paris Agreement, which aims to limit warming to between 1.5°C and 2°C, and the 2.6-3.1°C we are on course for by the end of the century under current climate plans.

Virtually no one believes the new plans will be ambitious enough to meet a 1.5°C pathway, says Alden Meyer at London-based think tank E3G. A UN synthesis report, due for release a few weeks before COP30 kicks off, will confirm how far off target the world remains. The challenge for the COP host is how to "squeeze out more ambition" during the summit, says Meyer. "We know already we are going to fall short... so there's two things you can do. You can either give up... or you can say 'No, that's not our final answer,'" he says.

2.6-3.1°C
Amount of warming projected by 2100 under current climate plans

$1.3 tn
Annual finance package for lower-income nations targeted by the COP29 agreement

One route to do that would be to focus on building up multinational partnerships on issues such as deforestation, electric vehicles and methane emission reduction. There could also be more emphasis on the work of states and cities to drive emissions cuts in their local jurisdictions, says Meyer.

"The theory is if you can get more happening on the ground in terms of actual emission reductions, countries might be willing to adjust upwards the ambition of their pledges," he says.

Money will be crucial to unlocking more ambition from lower-income nations. Disappointed at the lack of direct aid on offer from wealthier nations, they agreed to the COP29 package in Baku in part on the promise the next meeting would draw up a "road map" detailing how public and private sources would deliver the climate finance goal of $1.3 trillion per year. Ideas on the table include reform of multilateral development banks, taxes on aviation and shipping and levies on fossil fuels. Demonstrable progress in this area will be crucial if Brazil's goal of collaboration and cooperation is to be realised.

Much hope for a brighter future is riding on a successful COP30. But we would do well to remember that COPs can deliver only so much, says Meyer. "The problem is back in capitals, in terms of political will, leadership, the power of the fossil fuel industry," he says. "We're not bringing enough to the table at these meetings in terms of political will and ambition. That's what has really got to change." ▮

DOMINIKA ZARZYCKA/SOPA IMAGES/SHUTTERSTOCK

Activists calling for climate action at COP29 in Baku, Azerbaijan

Technology

Get ready for the rise of the robots

Jeremy Hsu

HUMANOID robots are poised to enter warehouses, automotive factories and even some homes in growing numbers in 2025 – but whether they can really take hold remains to be seen.

The machines in this new revolution will be different to existing working robots, which are primarily lone arms doing repetitive motions on assembly lines or wheeled bots navigating warehouses. Humanoid robots with two arms and legs should fit more easily into spaces designed for humans, but pulling that off will require much better artificial intelligence to handle such unpredictable environments. The hope is that recent advances in AI can be put to work in this way.

"There is a lot of optimism that ChatGPT-level models for robotics will soon be upon us," says Ed Colgate at Northwestern University in Illinois.

In both the US and China, a huge range of companies are planning to put humanoid robots to work in 2025. "While humanoids have been around for a long time, we've never seen anything like this," says Colgate.

First, there are the robots coming to car factories, which are already well experienced in using robot arms. The California-based start-up Figure – with financial backing from OpenAI, Microsoft and Nvidia – tested its humanoid robots in a BMW factory this year, with plans for a larger deployment in 2025. Texas-based Apptronik has been testing its Apollo robot in Mercedes-Benz facilities with the goal of commercialising the robot by the end of 2025. And Elon Musk has claimed that his company Tesla will begin producing its Optimus robot for internal use before the end of the coming year.

Warehouses could also soon be swarming with humanoid robots. Oregon-based Agility Robotics has trialled its Digit humanoid robot in Amazon facilities and already has units working commercially for a firm called GXO Logistics. In 2025, it plans to manufacture hundreds more robots ready to be put to work, with the capacity to eventually scale up to 10,000 robots per year.

A year of robot innovation

In China, where the government has declared 2025 a year for humanoid robot innovation, dozens of companies are racing to deploy their machines. For example, the Shanghai-based company Fourier has already delivered more than 100 humanoid GR-1 robots to manufacturing facilities and research institutions and in 2025 will focus on selling an upgraded GR-2 robot for more diverse uses.

Even ordinary homes could see robot helpers. The US-Norwegian company 1X – another robotics start-up backed by OpenAI – plans for its NEO robot to start organising and tidying homes during pilot tests in 2025.

The Digit robot made by Agility Robotics is already working in warehouses

AGILE ROBOTICS

DANIEL IRUNGU/EPA-EFE/SHUTTERSTOCK

Could robot servers be coming to a cafe near you?

So is this the beginning of a world that runs on robots? Maybe not. "People are still pretty cheap replacements for humanoid robots – I don't see many big applications where a humanoid makes economic sense," says Chris Atkeson at Carnegie Mellon University in Pennsylvania. "The 'killer' app is when a humanoid form is highly desirable, [such as] care and companionship robots."

One of the biggest issues for humanoid robots still yet to be solved is fully replicating the human hand. "Robot hands are just now getting pretty good at grasping, but human hands do so much more – we use them to manipulate the world in endlessly clever ways," says Colgate. "I will be pleasantly surprised if humanoid robots become prevalent in any application, no matter how niche, in the next decade." That means many human jobs should remain safely out of robot hands, for now. ▮

"HUMANOID ROBOTS HAVE EXISTED FOR A WHILE, BUT WE'VE NEVER SEEN ANYTHING LIKE THIS"

5

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Climate engineering

The big suck begins

A US plant will pull carbon out of Earth's atmosphere on a much greater scale

Madeleine Cuff

1POINTFIVE

Artist's rendering of the Stratos facility that is due to open in Texas

THE world's largest facility for removing carbon dioxide from the air is set to open in Texas in 2025, increasing the sector's worldwide capacity by a factor of 13.

Currently the largest direct air capture (DAC) plant in the world is in Iceland – the Mammoth site, built and operated by Swiss firm Climeworks. It opened in May 2024 and can extract up to 36,000 tonnes of CO_2 each year from Earth's atmosphere.

Stratos, due to start operating in the middle of next year, will dwarf that. The facility will be able to remove up to 500,000 tonnes of CO_2 per year when fully up and running, according to 1PointFive, an oil and gas company subsidiary that is building the complex.

Its opening will also shift industry attention from Europe to North America. A host of larger-scale projects are planned or under construction across that continent, fuelled by generous tax credits offered by the US government under the Inflation Reduction Act. That includes four DAC hubs backed by $3.5 billion of funding from the US Department of Energy. The aim is to create a market for carbon capture technology, which is expensive but seen as vital for offsetting hard-to-decarbonise sectors, such as aviation, as we strive for a net-zero world.

Stratos will act as the first clear indication that DAC technology is commercially viable, says Dawid Hanak at Teesside University, UK. "At the end of the day, there must be a business model behind it for DAC operators," he says.

The CO_2 captured at the Texas plant is likely to be stored underground, while the sale of carbon offset credits to large corporates will generate revenue. Microsoft, Amazon and TD Bank are among the firms signed up to buy these credits.

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"THIS PROJECT COULD GIVE INVESTORS THE CONFIDENCE TO INVEST IN SMALLER INNOVATORS"

500,000

Tonnes of CO_2 Stratos will draw out of the atmosphere each year

The price they are paying for this will be critical. 1PointFive says it expects carbon removal at Stratos to cost $400 to $500 per tonne, well above the $100 to $200 target developers hope to achieve for DAC by the end of the decade. Only a few large companies have pockets deep enough to pay for carbon removal at this rate and on this scale.

To drive costs down, further innovation is needed. The critical challenge for 2025 is for DAC to scale up without driving out the smaller players in the industry, as they tend to bring the kind of innovation we need, says Hanak. Such firms are developing novel DAC methods like electrochemical direct air capture, he says, a more energy efficient way of removing carbon from the atmosphere that uses electricity instead of heat and pressure. Hanak hopes these outfits will thrive: "The Stratos project could give investors the confidence to invest in smaller projects."

But DAC isn't without controversy. Occidental Petroleum, which owns 1PointFive, has made no secret of its desire to use captured CO_2 in enhanced oil recovery, where it is injected into reservoirs to help push out any remaining oil.

Occidental Petroleum describes oil produced through this process as "net zero oil" and says this approach will allow DAC to scale up fast, but many climate campaigners argue it will just prolong the use of fossil fuels and slow the global transition to green energy. "The ultimate use of captured CO_2 from Stratos will be driven by customer preference," Occidental Petroleum said in a statement.

Biotechnology

CRISPR pigs head to market

Pigs resistant to a common disease lead the way for gene-edited farm animals

Michael Le Page

THIRTY years after the first genetically modified tomato went on sale, the promise to revolutionise farming with genetic technologies remains largely unfulfilled. But 2025 could be a turning point, with new products demonstrating the untapped potential to reduce the losses of animals and crops to diseases.

In the coming year, regulatory authorities in the US are expected to approve a pig gene-edited to make it resistant to a common and devastating disease. That approval could open the door to a much wider use of the technology.

2025 should also see field trials in the Philippines of a banana altered to be resistant to a major fungal disease that has spread to many countries worldwide. If the Philippines adopts the banana, other countries may follow suit.

It is estimated that, globally, between 20 and 40 per cent of livestock and crops are lost to pests and diseases. Reducing these losses would have many benefits, from helping keep food prices down to making farming more profitable and reducing the environmental damage it causes.

"GENUS EXPECTS STRONG DEMAND GIVEN THE HUGE LOSSES FARMERS SUFFER"

In fact, making farm animals resistant to viruses such as flu could even help reduce the risk of another pandemic.

So far, however, so-called Bt crops designed to resist various pests are the only genetically modified (GM) plants of this kind to be widely grown. In 1998, GM papayas resistant to a viral disease saved Hawaii's papaya industry, but adoption of disease-resistant plants elsewhere has been slow because of opposition to GM foods. There is no large-scale production of any kind of GM animal.

The international breeding company Genus might just change this. It has used CRISPR gene editing to make four breeding lines of pigs resistant to the airborne virus that causes porcine reproductive and respiratory syndrome (PRRS). Production can fall 7 per cent on farms affected by PRRS, so it leads to major losses globally.

"We continue to make progress with FDA [US Food and Drug Administration] approval of our PRRS-resistant pigs, and are still on track for approval some time in 2025," says Clint Nesbitt at Genus.

20-40%
Estimated share of livestock and crops lost to pests and diseases

$2.7 bn
Estimated global cost to pig farmers related to the disease PRRS

7%
Fall in production on pig farms affected by PRRS

7
Genus's gene-edited pigs with resistance to the virus that causes PRRS

GENUS PIC

The rollout of the PRRS-resistant pigs will also depend on approval being granted in the major export markets for US pork, so sales might not begin until 2026. Once the necessary approvals are in place, Genus expects strong demand given the huge losses farmers suffer because of the disease.

Indeed, the head of a pig-producing company in the UK, Robert Beckett, has urged the UK government to approve the resistant pigs as soon as possible. "I am fully supportive of the adoption of the technology to help tackle the devastating condition of PRRS in the pig industry," says Beckett.

Another destructive disease is caused by a fungus called TR4 that infects and kills most edible bananas, including the world's most popular variety, the Cavendish. A team led by James Dale at the Queensland University of Technology in Australia has made the Cavendish banana resistant to TR4 by adding a gene from a wild banana.

These bananas have been approved in Australia, but the country is one of the few that is managing to keep TR4 under control. Wider adoption depends on the bananas' rollout in other countries, with field trials due to begin soon in the Philippines. "If all goes well, they should be planted in the field around the end of February," says Dale.

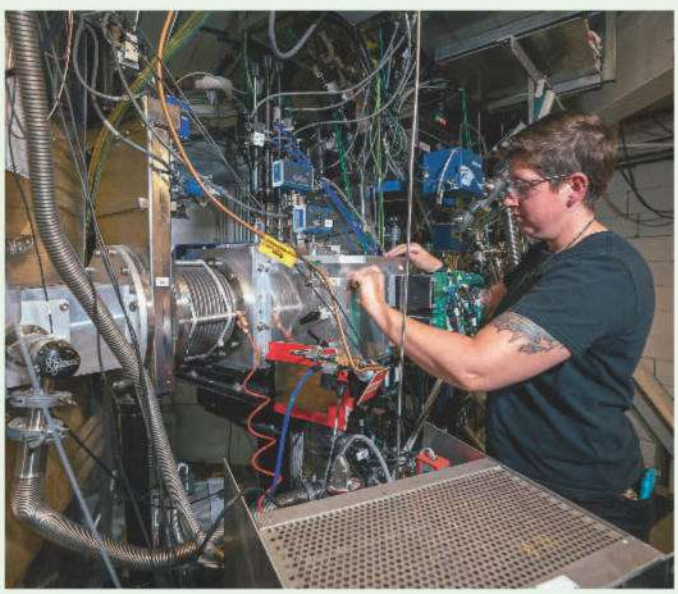
These fields trials were delayed by a Greenpeace-orchestrated court ruling that banned the growing of GM crops in the Philippines. This has been partially reversed, allowing the trials to go ahead, but the growth of golden rice modified to be richer in provitamin A remains banned.

Physics

The periodic table is due an ultra-heavy upgrade

Karmela Padavic-Callaghan

Above: The undiscovered element 120 is currently known as unbinilium
Right: Lawrence Berkeley National Laboratory aims to make heavier elements by firing titanium particles at a metal target



NEGRO ELKHA/ADOBESTOCK; MARILYN SARGENT/BERKELEY LAB

THE race to discover new chemical elements will heat up in 2025, resulting in the heaviest one so far and a new row added to the periodic table if successful.

"Patience will be the biggest challenge," says Jacklyn Gates at Lawrence Berkeley National Laboratory (LBNL) in California.

Gates and her colleagues are one of a number of teams attempting to produce element 120, also currently known as unbinilium. Attempts to forge such synthetic substances, which don't exist naturally on Earth, typically involve smashing a beam of charged atoms into a target made from a different, lighter element, in the hope that they fuse.

The LBNL team is planning to use a beam of titanium particles (element 22) and a target made from the radioactive element californium (element 98), providing the correct number of protons to reach the 120 required for unbinilium.

This experiment will rely on a key breakthrough made by LBNL in 2024, which saw it deploy a titanium beam for the first time to create livermorium (element 116), in this case by firing it at a piece of plutonium (element 94).

"This was a big step toward the success of the element 120 project," says team member Krzysztof Rykaczewski at Oak Ridge National Laboratory (ORNL) in Tennessee. Ever since, the team has shifted focus to the californium target, which is currently being made at a different facility.

Gates and her colleagues are having to adjust everything in their setup because californium is significantly more radioactive than plutonium. These, and any future, experimental tweaks come at a cost – mathematical models suggest that it may take hundreds of days to produce just a single unbinilium atom and every time the experiment gets adjusted, that clock will reset, says Gates.

Because of this, the search may end up being slow and could carry over into 2026 or even 2027, though the team is hoping to get lucky.

Elsewhere, Hiromitsu Haba and Kouji Morimoto are part of a team at RIKEN in Japan that is using a beam of vanadium (element 23) and targets made from curium (element 96) to try to create element 119, or ununennium, and which has also never been synthesised, making it a contender in the race for a new heaviest element. The pair declined to comment on the progress of their search.

Other teams hoping to claim the prize include one at the Institute of Modern Physics of the Chinese Academy of Sciences, and one at the Joint Institute for Nuclear Research (JINR) in Russia – the current record holder, having first synthesised oganesson (element 118) in 2002. This addition to the periodic table sits at its bottom right corner, meaning the discovery of elements 119 or 120 would require a new row.

Up until February 2022, JINR was collaborating with ORNL and Rykaczewski says that a californium target for that experiment was ready for a flight to Moscow, but the project ended abruptly when Russia invaded Ukraine. Preliminary results were promising, yet never published, says Rykaczewski. Whether the work at JINR can continue without ORNL is uncertain.

Whoever wins the race, everyone is keen to see what the ultra-heavy echelons of the periodic table have in store for us. "Obviously, we would like to discover element 120 first. But if somebody else discovers it, I think that's still like a really great thing for the field, I would be happy for anyone," says Gates. ▮

"OBVIOUSLY, WE WOULD LIKE TO DISCOVER ELEMENT 120 BEFORE ANYONE ELSE"

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Space exploration

Lunar invasion

Both government and commercial activity on the moon are set to increase in 2025

Leah Crane

AROUND a dozen landers are aiming for touchdown on the lunar surface next year, with the goal of developing the technology necessary to build a permanent human presence there.

This fusillade of launches is part of an ongoing campaign to ramp up exploration of the moon, fuelled in part by NASA's Commercial Lunar Payload Services (CLPS) programme. This involves funding spacecraft from private companies, which carry a combination of NASA's own science instruments and payloads from other customers.

"Longer term, [CLPS] is playing a big role in ushering in new commercial lunar technologies," says Jana Spruce at Firefly Aerospace, a launch company based in Texas. "We're seeing a broad range of interest from commercial companies, universities and research institutes looking to demonstrate technologies that can help build the foundation of lunar infrastructure, unlock the moon's resources and support research for a lasting presence on the moon."

Firefly's Blue Ghost lander is expected to launch in mid-January, making it the first of the year's many lunar jaunts. It will carry a variety of instruments, ranging from X-ray cameras and a lunar navigation system to a drill to measure heat transmission.

Time for the sequel

Following close on its heels will be IM-2, another CLPS mission, by Intuitive Machines. In 2024, the company became the first private firm to achieve a successful landing on the moon, and this next mission promises to be just as thrilling. Its primary purpose is to drill near the south pole of the moon to collect and analyse samples of buried ice that may be useful for future missions. It will also carry several other small spacecraft, including a tiny "hopper" rover to explore hard-to-reach areas of the moon, another small rover to collect samples for NASA, and a satellite to facilitate communications between all the spacecraft and operators on Earth.

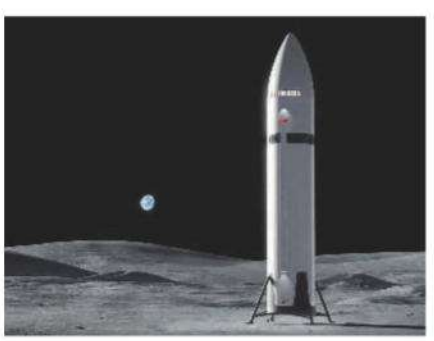
"We're eager to collect science data that will provide hi-res maps of water, minerals and thermophysical properties to guide the next generation of landed missions," says Bethany Ehlmann at the California Institute of Technology, leader of a team that will work on mapping the moon through the Lunar Trailblazer orbiter, which will also be part of the IM-2 mission.

Later in the year, Intuitive Machines will send yet another lander, IM-3, to a strange magnetic feature called a lunar swirl. A few more CLPS missions are planned for the year as well.

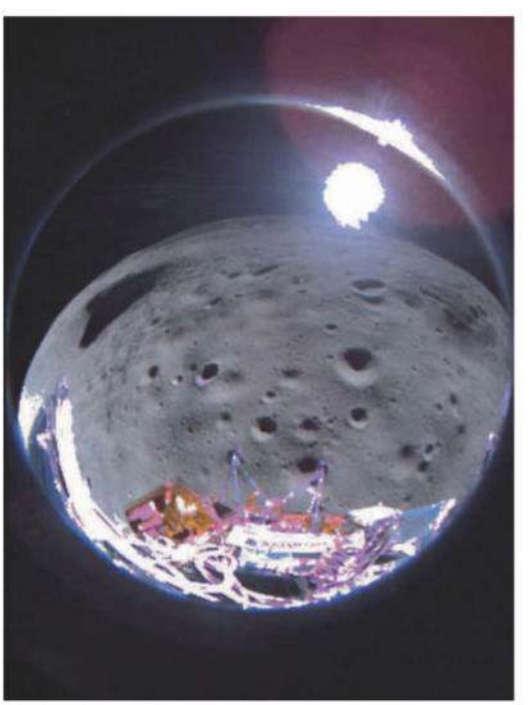
Israeli company SpaceIL is also taking another shot at the moon in 2025 with Beresheet 2 – a follow-up to the first Beresheet mission, which crashed on the moon in 2019. This second attempt will include two landers in the hope of exploring two separate regions on the lunar surface, along with an orbiter.

Sadly, 2025 won't see a crewed launch to the moon as NASA's Artemis II mission – which aims to take four crew members around the moon and back to Earth without landing – has been delayed until 2026. The closest we will get is a planned uncrewed landing of SpaceX's Starship Human Landing System there, the same spacecraft intended to shuttle astronauts to the lunar surface in 2027 as part of NASA's Artemis III mission.

> "WE WANT TO UNLOCK THE MOON'S RESOURCES FOR A LASTING LUNAR PRESENCE"



SPACEX, FIREFLY AEROSPACE



INTUITIVE MACHINES/UPI/SHUTTERSTOCK

Clockwise from main image: Intuitive Machines' Odysseus spacecraft captured the lunar surface in 2024; Firefly's Blue Ghost lander is being prepared for launch in January; SpaceX wants to land its Starship rocket on the moon

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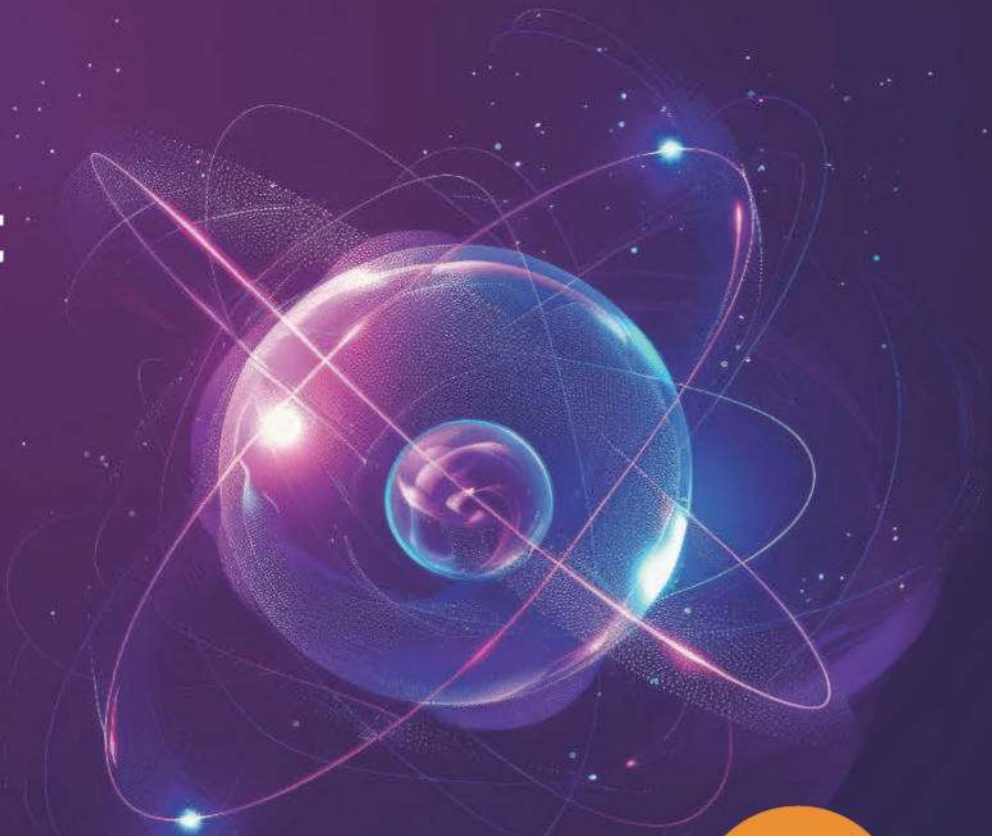
New Scientist
Events



Instant Expert

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Culture columnist
Emily H. Wilson picks the sci-fi books to savour in 2025 p26

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Comment

Not OK, computer?

Some prominent researchers argue that we should pay heed to the welfare of AIs. Are they right, wonders **Alex Wilkins**

ELAINE KNOX

IS YOUR chatbot in distress? Many people, myself included, would scoff at this question. It is just computer code, optimised to predict the next word in a sequence. But some philosophers and psychologists say that we shouldn't be so quick to dismiss this question, perhaps even granting chatbots their own rights. They might have a point.

In a recent academic paper, "Taking AI Welfare Seriously", one group of researchers argue for a precautionary approach to how we treat AIs. They don't look to answer the question of whether an AI is conscious or not, but say we should start investigating the issue more thoughtfully. We probably won't find the answer tomorrow, or even within 10 years, but major societal consequences are dependent on it, they say.

"It's not that we can be confident that AI systems are conscious or agentic or otherwise morally significant," says Jeff Sebo at New York University, one of the authors of the paper. However, as "mistakes in either direction can be harmful", and there is likely to be uncertainty about these issues for some time, Sebo says we need to start developing "thoughtful" policies "sooner rather than later".

A dystopian future where we take advantage of sentient AIs would be horrific. But one where we ascribe consciousness to entities that aren't would also be worrying, as we might waste time and energy protecting AIs.

We should start planning for both scenarios, write Sebo and his team, by actively investigating AIs for signs of consciousness, and preparing "policies and procedures for treating AI systems with an appropriate level of moral concern". The "we" refers to AI companies, of which just a few have the means to push the frontier of development and investigate these issues.

According to the paper, one way that companies could do this is by appointing an AI welfare officer, a person who would be tasked with building "a structure for assessing AI systems for moral patienthood and making decisions about how to treat them". Kyle Fish, one of Sebo's coauthors, has been employed to do this by AI startup Anthropic, developer of the Claude chatbot.

It is worth stating that Sebo's thinking here is closely related to his work on animal consciousness. He was one of 40 scientists who initially signed The New York Declaration on Animal Consciousness in April, which cites "strong scientific support for attributions of conscious experience" in mammals and birds. Sebo foresees AI and animals forming a greater group with non-human consciousness. But while the philosophical parallels for both are clear, the evidence base for each seems, to me, quite different. Animal consciousness has been investigated for decades, while competent AI systems have only just been invented.

In any event, assertions of AI consciousness are being made. In 2022, an ex-Google engineer made headlines by saying that the company's earlier chatbot, LaMDA, showed signs of sentience, a claim which Google and the wider AI community pushed back against.

With millions of us interacting with AI, pronouncements like this will only become more frequent. Whether a claim about AI sentience from an AI company will sway public opinion is unclear. But the issue seems worth devoting some effort to, so when lawmakers inevitably have to rule on the interactions we have with AIs, they have proper evidence about what is going on in these machines.

So I will hold my scoffing for now, if only on the off chance that it helps avoid the remote scenario where a bot becomes aware of its fate, like Marvin the depressed android in *The Hitchhiker's Guide to the Galaxy,* who laments: "Here I am, brain the size of a planet and they ask me to take you down to the bridge. Call that job satisfaction? 'Cos I don't."

Alex Wilkins is a reporter at *New Scientist*

Field notes from space-time

Through a glass, darkly

Around the middle of 2025, the Vera C. Rubin Observatory will begin its mission to help us better understand the cosmos. **Chanda Prescod-Weinstein** can't wait

Chanda Prescod-Weinstein is an associate professor of physics and astronomy, and a core faculty member in women's studies at the University of New Hampshire. Her most recent book is *The Disordered Cosmos: A journey into dark matter, spacetime, and dreams deferred*

Chanda's week

What I'm reading
I'm enjoying Koji Suzuki's sci-fi novel Edge*.*

What I'm watching
I'm pretty excited to watch season two of Silo*, a sci-fi show about a working-class woman engineer.*

What I'm working on
Digging into a new project on the effects of dark matter in the early universe.

This column appears monthly. Up next week: Graham Lawton

SOMETIME in May or June, as the southern hemisphere winter sets in beneath the skies of the Chilean Atacama desert, the Vera C. Rubin Observatory will open its dome and the largest digital camera in history will capture its first science-grade image of the cosmos. Under the Atacama's pristine and stable atmosphere, Rubin will begin a 10-year mission to provide humanity with an extraordinary new vision of the cosmos with the Legacy Survey of Space and Time (LSST).

Twenty-four years in the making, the observatory is a brand new astronomical facility. To get a sense of what I mean when I say it will have the largest digital camera in history, imagine if the camera on your mobile phone were over 1.5 metres wide, 1000 times more powerful and weighed as much as a car. That's LSSTCam, which (as of time of writing) is expected to capture photons from the Atacama sky for the first time on New Year's Day. It is paired with one of the largest telescopes ever built – 8.4 metres across – giving us a brilliant new instrument for night sky observation.

The fundamental science mission of LSST is to scan the entire night sky every few days, returning a time-lapsed high-definition recording of the universe. Using this data, the thousands of scientists around the world working on this project will be able to investigate questions of great cosmological significance. For example, as a member of the Dark Matter Working Group, I am excited to get high-quality data about our galaxy, the Milky Way, and its local galactic group.

You might wonder what looking at the local group could possibly have to do with understanding dark matter, which is a phenomenon we can't see with a telescope. There are a few exciting science opportunities here. Rubin will search for evidence of extremely faint satellite galaxies that are gravitationally bound to the Milky Way and its neighbouring galaxy Andromeda. Understanding how many such galaxies there are in the neighbourhood will help us get a robust sense of which objects are gravitationally affecting our galaxy and its dark matter halo.

Rubin will also capture information about more than 10 billion stars and the dust that surrounds and produces them.

> **"It will have the largest ever digital camera – imagine if your phone's camera were over 1.5 metres wide"**

This information will provide new insights into the structure and evolution of our home galaxy and its neighbours. Because we expect most, if not all, galaxies to be suffused with dark matter, we know that how stars are moving, where they are and even their formation rate is shaped by the presence of dark matter.

Better understanding what we can see allows us to reverse engineer the behaviour of what we can't see. This dataset will build on previous sky surveys, so when we talk about 10 years of data, we are really talking about 10 years of higher-definition data supporting a multi-decade mission to map our local galactic neighbourhood.

The beginning of scientific work with the Vera C. Rubin Observatory is a reminder that Earth is a multigenerational spaceship, filled with incredible scientific missions that take a long time to complete. In the 1960s, when Vera Rubin and Kent Ford began collecting the data that ultimately convinced the global astrophysics community that dark matter truly existed, the precursors to charge-coupled devices (CCDs), which behave like digital film, were in development at Bell Labs, New Jersey. At the time, it was unimaginable that we might one day have people-sized CCD cameras. Yet that is exactly what LSSTCam is.

At the time of Rubin and Ford's work, scientists had no idea that the expansion of space-time was picking up speed. Today, understanding the nature of cosmic acceleration and whether it is caused by something called dark energy is a major driver of research in cosmology. The international collaboration that forms the LSST community will be working across borders to try to understand the fundamental structure of space-time.

I couldn't be more excited for the Vera C. Rubin Observatory as a technological feat and a science mission. As someone who was first inspired to think about dark matter by a question from Rubin herself, I love being part of a project that honours her memory by furthering her endeavour to understand galaxies. I am also grateful that the Rubin community makes an effort to understand itself through an international lens. Since the project is hosted by the people of Chile, translating key documents, from our science glossary to our outreach materials, into Spanish has been a priority.

Like the European particle physics facility CERN, Rubin is offering an example of peaceful global cooperation. This is the kind of humanist vision we need to hold on to as we enter 2025. ▮

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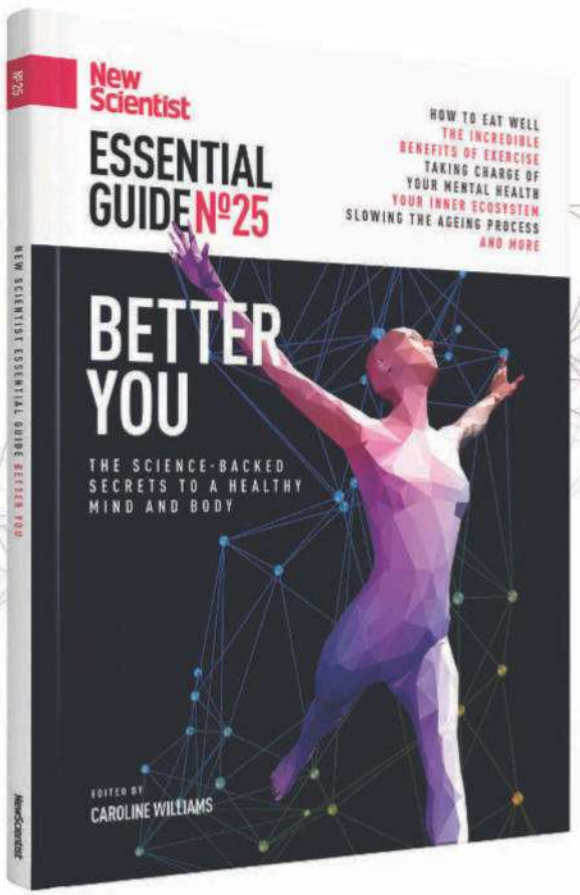

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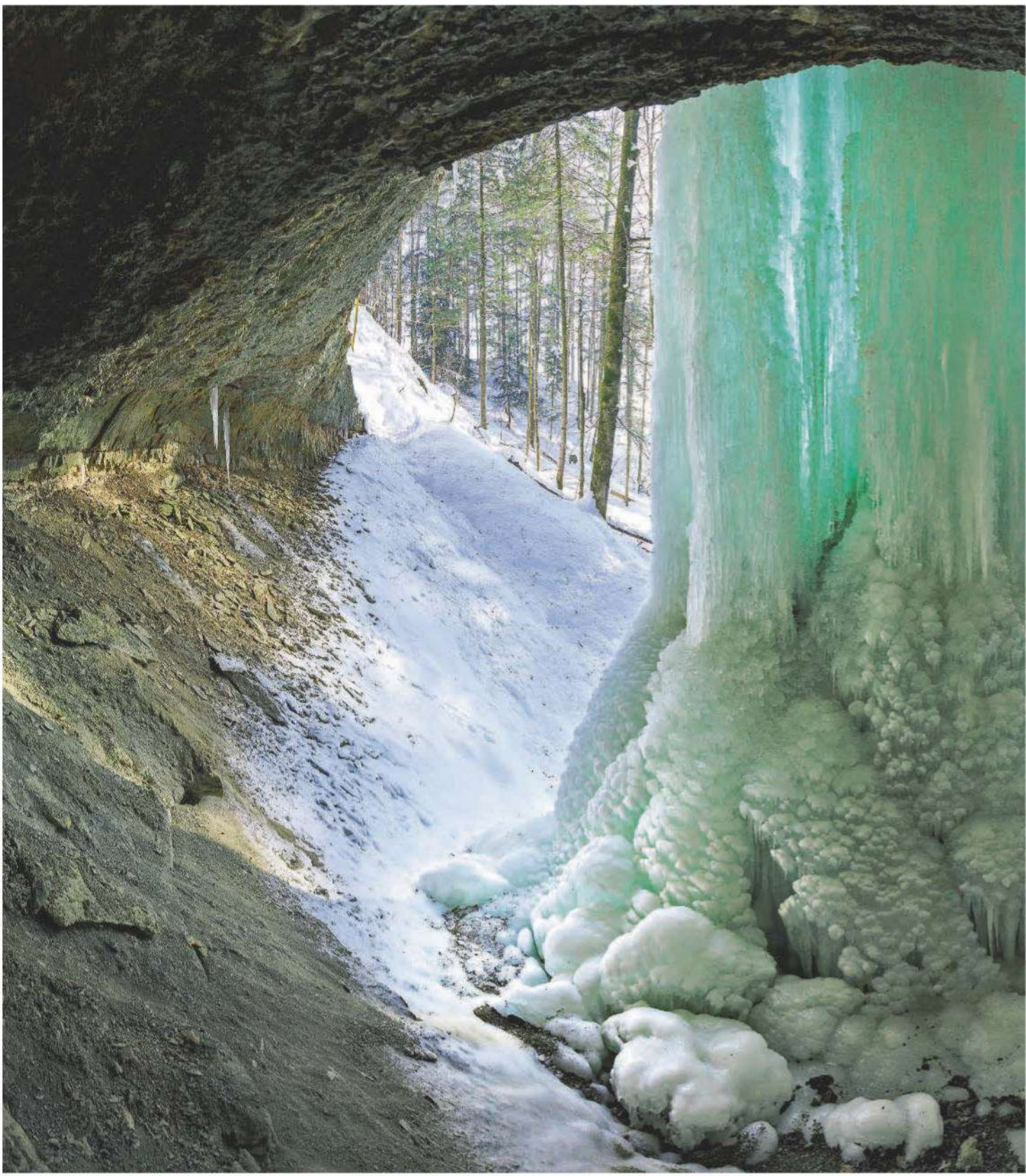
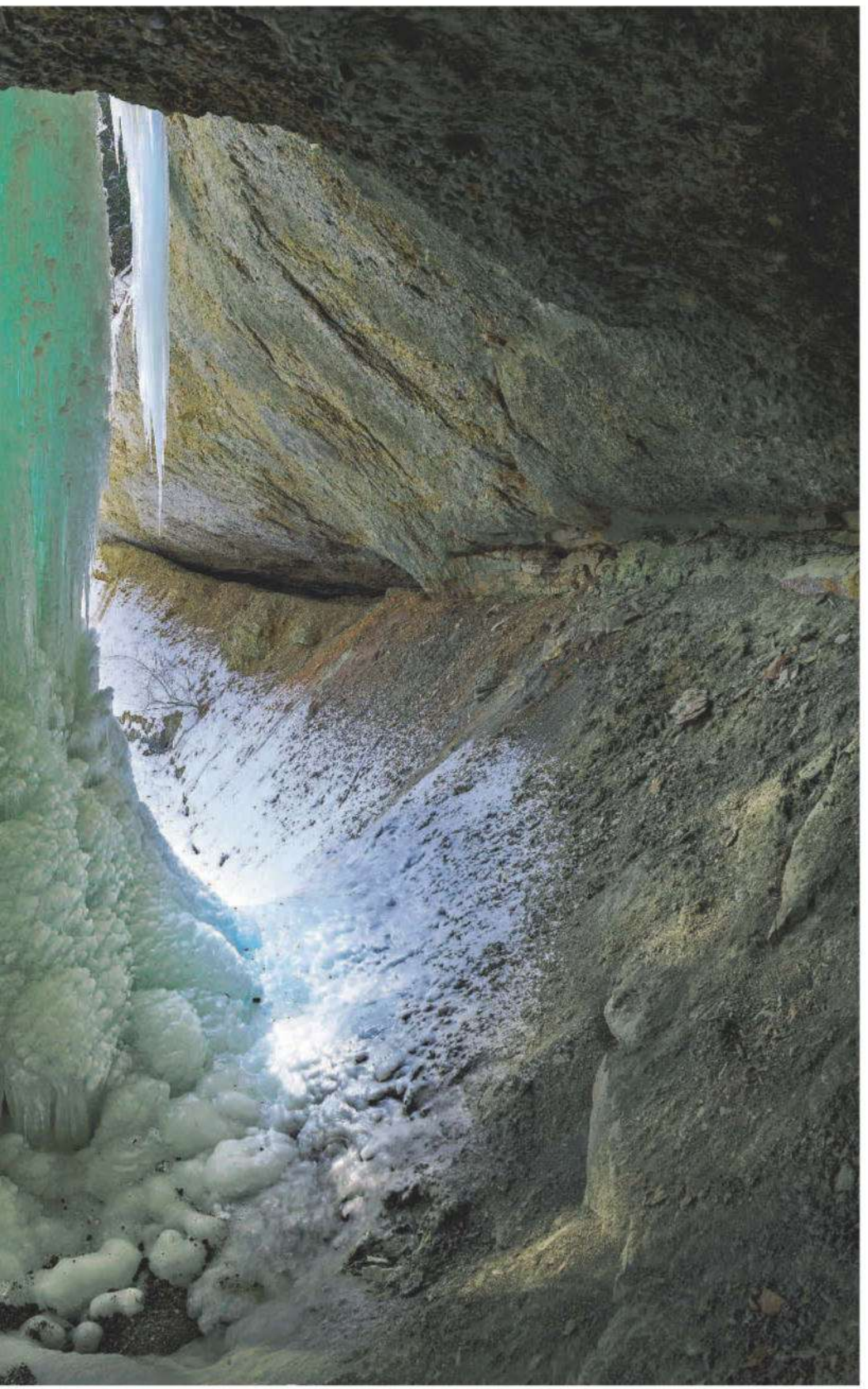




Frozen planet

Michael Hambrey & Jürg Alean
Papadakis Publisher

A GIANT, impossible icicle. Starkly exposed mountain slopes. Billion-year-old rocks behind a lone iceberg. And the view from within a glacial tunnel.

These four beautiful and moving images (left and following two pages) come from a new book, *Our Frozen Planet* by Michael Hambrey and Jürg Alean. It sets out to celebrate the cryosphere – the collective noun that describes the world's ice in all its forms, from glaciers and ice sheets to permafrost and snow cover.

The largest image of the four (left) shows ice that has formed around a waterfall near Giswil, Switzerland. Icicles growing from the top have fused with ice formations emerging from the bottom to create a giant ice column.

On the following pages, clockwise from top left, is Bryce Canyon in Utah. The direction of a slope strongly affects how snow is distributed in mountainous areas. Almost all the snow has melted on the south-facing slope of this ridge, but a substantial cover remains on the shady, north-facing left side.

The image to the right shows Nordvestfjord, in Northeast Greenland National Park, where some of the world's oldest metamorphic rock forms a backdrop to an iceberg reflected in the deep fjord's waters.

In Switzerland's Vadret da Morteratsch glacier (bottom left), meltwater has carved a tunnel through the snow and ice. The photo was taken from inside the tunnel in winter when no meltwater was flowing through.

Liz Else

Restock your mind in 2025

Understanding why we think the way we do is a hot topic for many of 2025's books – that and finding new ways to re-evaluate old "truths", says **Simon Ings**

AN INCREASINGLY divisive politics. Media technologies that reinforce and radicalise every fleeting opinion. An absolute tsunami of conspiracy theories.

Out of the noise and anxiety of our current moment comes a slew of new books that may make 2025 the moment humanity turned a corner, and replaced the heat of partisanship and tribalism with enlightened discourse and real debate. Many of them explain why we think the way we do about the world, and show us how we can change our minds without losing them in the process. They are informed by new and freshly interpreted data, and sometimes showcase years of original study.

Joe Pierre's *False* (Oxford University Press, June) is the most direct of them: a decades-in-the-making examination of rule-of-thumb thinking (without which we couldn't function) and how it necessarily gives rise to a long list of demons – think cognitive bias, cognitive dissonance and much more. So the Enlightenment idea of a life lived according to the dictates of reason isn't wrong exactly, but we have to be realistic about how our minds actually work.

What we absolutely cannot afford to do is to stop thinking, in the fond hope that we can simply "follow the data". *Think Clearly* (W. H. Allen, January) by data journalist Kiko Llaneras makes this point very well, while still being a refreshingly positive take on number and measurement.

"The more we understand just why we disagree, the calmer our discourse becomes"

The trick to thinking with data is to stop taking the stuff on trust, and start learning how to use it. Practical tools and shortcuts make this a compelling, intellectual self-help book.

For those who want a deeper take on our relationship with data, here are two promising new books. *The Measure of Progress* (Princeton University Press, April) leverages author Diane Coyle's work in public policy to argue that, as societies change their character, the kind of data they collect must also change. For example, gross domestic product (GDP) was an excellent index of societal health in the 1940s. Assuming it works as well now is just lazy.

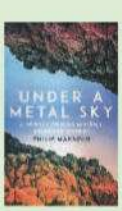
Maja Bak Herrie, meanwhile, is interested in how we perceive, and misperceive, even the most appropriate data. *Thinking Through Data* (Stanford University Press, March) shows how visualising data triggers all sorts of aesthetic biases. A picture may be worth a thousand words, but the truth buried in that picture is still hard to get at.

In *Proof* (Profile Books, March), Adam Kucharski explains why getting at the truth of just about anything is incredibly hard. There's fascinating technical detail here, and a moral: the more we appreciate how hard proof is to come by, the better we can bridge the widening gulf between experts and sceptics. To put this another way: the more we understand just why we disagree, the calmer our discourse becomes.

In that spirit, dyed-in-the-wool atheists really should have a look at *Why We Believe* (Oneworld, January) by the Christian apologist Alister McGrath. Accepting the unknown isn't a failure of rational thought, he says, but an existential necessity. Cynics may well say that he is riding psychology's coat-tails to slip one by us; this atheist isn't so sure.

By the way, did the mention of

From rocks to hard places



What we create depends on what we can extract from Earth. Philip Marsden's *Under a Metal Sky* (Granta, February) turns this plain proposition into a tale of struggle, innovation and the odd catastrophe.

But some of these materials come from space: the earliest iron artefacts were smelted from meteorites. *New Scientist*'s Joshua Howgego's *The Meteorite Hunters* (Oneworld, February) tells the stories of the world's best meteorite hunters and reveals what we can learn about the history of the solar system from their findings. Astronomer Govert Schilling is more interested in the space rocks hurtling towards us in *Target Earth* (The MIT Press, April).

But let's not forget how Earth is holding up right now. Friederike Otto's *Climate Injustice* (Greystone Books, May) looks at the impact of extreme weather on the world's most vulnerable, while Mike Berners-Lee's *A Climate of Truth* (Cambridge University Press, March) explores why, when we have most of the technology we need to combat the climate crisis, we still aren't doing enough.

LECHATNOIR/GETTY IMAGES

The weather outside may be frightful but the new books inside are delighful

that last book – which argues that believing without evidence isn't at all a bad thing – evoke your scepticism? Fair enough. Did it raise your hackles, or even offend you? Then you may be suffering from cognitive rigidity.

Two of next year's books hammer home the obvious but oh-so-welcome point that it doesn't matter nearly so much what you believe as how you believe it. Paul Dolan's *Beliefism* (The Bridge Street Press, May) gives the lie to the idea that fixed beliefs are our only defence against witless credulity. Truths are complex, and this means that those who disagree with us are almost certain to be right about something. What we need, and rather desperately, is a return to ideas of citizenship that value agreement.

The neuroscientist (of politics) Leor Zmigrod brings fascinating original experimental work to bear here in *The Ideological Brain* (Viking, March). For instance, she demonstrates how a simple card-sorting game can reveal one's entire approach to life: struggling to adapt to new rules in such tasks apparently mirrors the rigidity with which you hang onto social and political ideologies. We can all try to be more flexible, but some of us are more susceptible to dogmatic thinking. If I had to pick one, Zmigrod's would be my book to watch out for in 2025.

Of course, it may help to remember that the brain itself is a hypothesis generator. After all, if we couldn't imagine, we wouldn't perceive anything. In *The Shape of Unseen Things* (Bloomsbury Circus, January), neurologist Adam Zeman reveals just how radically different we all are, even as we reach common conclusions about a shared world. Pria Anand explores similar territory through an account of her clinical practice. In *The Mind Electric* (Virago, June), she shares the strangeness and sheer wonder of our brains in a testament to the wildness inside us all.

Elsewhere, Ciara Greene and Gillian Murphy's *Memory Lane* (Princeton University Press, March) shows how we use our brains for things they weren't necessarily evolved for, and argues that maintaining mental stability is more of a communal effort than we like to admit. Indeed, other people actually keep us healthy – they are our best medicine, says Nicole Karlis in *Your Brain on Altruism* (University of California Press, March), a powerful reminder of the importance and power of connection in crisis-filled times. ▮

Simon Ings is a writer and critic based in London. He writes *New Scientist*'s film column

Evolution and other relationships

Foundational theories say little about how living things evolve other than by natural selection. John Damuth and Lev Ginzburg's heavyweight *Nonadaptive Selection* (University of Chicago Press, July) is a rare journey into a different and important force at work beyond the individual level.

Sophie Pavelle's *To Have or to Hold* (Bloomsbury Wildlife, May) spins symbiosis for the lay reader, while our relationship with plants in particular is the focus of Robert Spengler's *Nature's Greatest Success* (University of California Press, May).

Robert Macfarlane's *Is A River Alive?* (Hamish Hamilton, May) explores the idea that a river can be a living being, answering the question of its title with a resounding affirmative.

In *The Elephant in the Room* (University of Chicago Press, May), Liz Kalaugher reveals the risks when we run roughshod over ecologies we don't fully understand.

And *Nature's Genius* (Canongate, May) by David Farrier argues that one day we will not only understand ecologies, but will be able to assemble them.

Smothered mothers

It is no secret that one of the least tolerable aspects of motherhood is other people's expert advice.

Two books bravely hack away at this ever-burgeoning thicket of good counsel. Alex Bollen's *Motherdom* (Verso, March) explains how hoary, old, nature-versus-nurture cliches have stuck mothers in a place where they can do no right. And Hannah Zeavin's *Mother Media* (The MIT Press, April) shows how the technology that is supposed to help makes this even worse.

Browbeaten and exasperated by all that oh-so-helpful guidance, a pregnant Helen Jukes turned to the natural world for solace.

***Mother Animal* (Elliott & Thompson, February) is her evidenced, coherent and passionate plea to revalue and celebrate motherhood in the light of how the whole process works in the real world.**

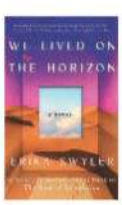
Anna Blix's *40 Weeks* (Hachette, March) is a perfect companion to Jukes's work. It is also built around the author's pregnancy, but this book is altogether more wild and wonderful in its scope.

Best sci-fi for a great new year

A Ken Liu thriller, two Adrian Tchaikovsky novels, *Succession*-style drama (with added telepathy) and a Polish epic. **Emily H. Wilson** surveys 2025's sci-fi

I AM writing this without (so far) having read any of the books I mention, but I believe that 2025 is shaping up to be a good year for science fiction. From what I can see, there is a lot of "literary" sci-fi coming our way, but perhaps less of the physics and spaceship heavy stuff, which won't suit everyone. But that may well change as new titles are announced. Here is my pick of upcoming offerings.

In January, we have *All the Water in the World* (St Martin's Press) by Eiren Caffall, a novel set partly on the roof of the American Museum of Natural History in New York in a flooded future. It is said to be inspired by curators in Iraq and Leningrad who worked to protect collections there from war. We will also have *We Lived on the Horizon* (Atria Books) by bestselling author Erica Swyler. Early information describes it as "a novel about a bio-prosthetic surgeon and her personal AI as they are drawn into a revolution".



February is set to be a packed month for new releases in the book stores. First off, there is *Death of the Author* (Gollancz) by Nnedi Okorafor. The award-winning writer brings us a story about a Nigerian American with disabilities "who writes a science fiction novel that becomes a global phenomenon... but at a price". I am intrigued. The same month, the ever-inventive Adrian Tchaikovsky returns with *Shroud* (Pan Macmillan), the story of two scientists crashing on a hostile alien moon. I am always happy to read a new Tchaikovsky.

There will also be two novels set in Antarctica. *Symbiote* (Angry Robot) is by Michael Nayak, whose work as a researcher on the frigid continent may bring a sizeable dose of authenticity to his tale of a biological threat at the South Pole. And in *Whiteout* (HarperCollins), by R.S. Burnett, a woman is left stranded on the ice by nuclear war.

March sees two comic offerings. *When the Moon Hits Your Eye* (Pan Macmillan) by John Scalzi is about the titular object turning to cheese. Meanwhile, *Space Brooms!* (Angry Robot) by A. G. Rodriguez involves a custodian on a space station. Less humorous will be the fifth entry in Suzanne Collins's *Hunger Games* canon, a second prequel entitled *Sunrise on the Reaping* (Scholastic).

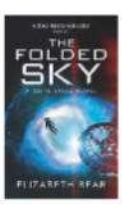
Voyages, both interstellar and Earth-bound, frame many new sci-fi novels

SHUTTERSTOCK/PHOTOCREO MICHAL BEDNAREK

In April, I like the look of *Gifted & Talented* (Pan Macmillan) by Olivie Blake, the plot of which sounds like *Succession,* except that here the children are telepathic. Then there is *Notes from a Regicide* (Tor Publishing) by Isaac Fellman. It is billed as "a heartbreaking story of trans self-discovery with a science fiction twist". Finally in this packed month, I'm looking forward to *Down in the Sea of Angels* (Angry Robot) by Khan Wong, marketed as "an intense and thoughtful time-travelling dystopian fantasy where three individuals, psychically linked through time, fight enslavement, exploitation, and environmental collapse".

Skipping on to June, we have another Adrian Tchaikovsky release. *Bee Speaker* (Bloomsbury) is the third in a series set in a future where "bioforms" have inherited Earth. I will be belatedly catching up on the rest of the series (*Dogs of War* and *Bear Head*) in preparation.

In the first half of the year, I am also looking forward to *The Dream Hotel* by Pulitzer Prize finalist Laila Lalami. It is set in a near future in which even our dreams are under surveillance. I also like the sound of *The Folded Sky* (Brown Books) by the Hugo award winner Elizabeth Bear, about an interstellar journey across the Milky Way to connect with an artificial intelligence.



Later on we have *Automatic Noodle* (Tor Publishing), out in August. It is by the acclaimed sci-fi writer (and my *New Scientist* colleague) Annalee Newitz and is billed as a "cosy, near-future novella" concerning a crew of abandoned food service bots opening their own restaurant.

Moving on to October, which sees the publication of Ken Liu's *Dreamshore Guardian* (Head of Zeus). Liu is a huge name in sci-fi and his new novel is marketed as the first in a new trilogy of dark, cyberpunk thrillers, which is quite exciting.

Last of all, in November, comes *Ice* (Bloomsbury Publishing) by Jacek Dukaj. It is the first time this epic story of an extraordinary voyage has been translated (by Ursula Phillips) from Polish, and the press release claims it "could be the most monumental work of literary science fiction published in the 21st century", so I feel I must definitely give it a go.

Here's to another happy year of sci-fi reading! ▮

Emily H. Wilson is the author of *Inanna* and *Gilgamesh*, set in ancient Mesopotamia. The third in the series, *Ninshubar*, is due out next year

Editor's pick

When eating out, try the secret sauce diet

30 November, p 14

From Jon Arch, Welwyn Garden City, Hertfordshire, UK

When it comes to calorie counts on menus as a nudge to eat more healthily, it is clear to me that a large proportion of calories in some meals are in the sauce. Restaurants don't mind showing the inflated calorie count because it doesn't deter the average customer. Having studied energy balance in obesity, for me the answer is simple: hold the sauce.

Plant cooling sounds fine, but only if it's kept green

23 November, p 36

From Florence Leroy, Swindon, Wiltshire, UK

The idea of using vegetation on buildings to cool them in hot climates is interesting. However, an architect friend fears certain problems. The last thing you want around buildings and walls is something that can catch and propagate fire easily. Dried plants (in very hot climates) potentially could. Installing vegetation on balconies or roofs presupposes a system will be in place and maintained to make sure the plants don't dry up and die, which could increase cost tremendously.

Women probably invented the wheel

23 November, p 17

From Bonita Ely, Sydney, Australia

Having given birth to a daughter whose size and weight increased over the years, necessitating the use of a pram, stroller, trolley, cart and motor vehicle, I have always suspected that women invented the wheel. This was reinforced by my daughter's instinctive preference for any toy with wheels, and her invention of a skateboard carriage for her pet cat, Freckles.

The 12,000-year-old wheel-like stones resembling spindle whorls invented to spin thread, that you report on, would certainly have inspired overburdened women, during a further 6000 years, to develop wheeled vehicles.

Sci-fi may be a truly ancient genre

Leader, 30 November

From Sam Edge, Ringwood, Hampshire, UK

Frankenstein is one of my favourite novels. However, I, like many others, contest the notion that it is the first science fiction.

There are many prior examples of what we would today consider sci-fi, if we define that as proposing a novel technology for the time and exploring the consequences.

For instance, in the 1600s, Church of England bishop Francis Godwin wrote *The Man in the Moone*, an account of a trip to the moon using a flock of swans harnessed to a vessel. At the time, it was a scientifically acceptable proposition that missing birds migrated to the moon in winter, so this would be what we now call "hard sci-fi", proposing a scientifically plausible scenario. He even described the low gravity on the moon. I could go on.

Mars colony: it would be a valuable back-up plan

16 November, p 40

From Len Mann, Gerrards Cross, Buckinghamshire, UK

I have digested the explanations for why trying to live on Mars is a bad idea. Very good points are made, but one important thing is missed. One day, a disaster will befall Earth that will most likely wipe out the human race. It might be an extinction type asteroid impact, a nuclear war, a pandemic, global warming or something we haven't thought of yet. If you think we should do our very best to preserve our species, then I believe that Mars is pivotal.

We don't even need to fully colonise it. When visiting Mars, people would need to stay for at least a year because of orbital dynamics. A transient colony of a few thousand could be maintained on an ongoing basis. At least then we would have the possibility of recolonising Earth after a disaster.

Why haven't chimps made a greater leap forward?

30 November, p 13

From Eric Kvaalen, Les Essarts-le-Roi, France

If chimpanzee communities are becoming more technologically advanced over time, why is it that after millions of years of existence all they can manage is to use sticks to fish for termites? Their tools may be biodegradable, but they don't make baskets, ropes or other things our ancestors probably did.

Technology is spoiling the beautiful game

23 November, p 40

From Jorge Pardo, Reston, Virginia, US

Throwing more technology at football's video assistant referee system is the wrong approach to its perceived problems.

Alongside football's fundamental character, which places human deceit above brute force (as Maradona described it), one of the arguably beneficial features of the game is the reliance on the judgement of its arbiters. This involves acknowledging their human limitations and contributes one more factor to the randomness that attracts, as much as it dismays, its fans.

Burdening a game that was adopted worldwide for its beauty, and its sparse need for equipment, with more cameras, sensors and statistical models will make it less economically practical in many countries.

One big solution for food could transform things

16 November, p 36

From Andrew Benton, Flourtown, Pennsylvania, US

"Recipe for disaster" certainly got my attention. It made it clear just how serious a matter climate change is likely to be for farming and food production. It then talks about solutions, stating: one big answer is eating less meat.

The article later advised against buying organic food because it isn't as efficient per hectare of land. Well, if the world took the big solution seriously and reduced meat and dairy consumption, we would need only a fraction of the land to grow enough food, and we could rewild the rest of it.

Organic farming is about sustainability, creating healthy soils and treating animals well. What is the point of efficiency if we continue to lose topsoil? On top of that, agrochemicals are energy intensive, thus adding to carbon emissions.

More than microbial DNA on asteroid sample?

30 November, p 15

From Andrew Summers, East Coker, Somerset, UK

My only surprise was that the researchers looking down their microscope at asteroid rock samples only saw terrestrial bacterial contamination and not golden retriever dog hair, which permeates the entire universe.

Want to get in touch?

Send letters to letters@newscientist.com; see terms at newscientist.com/letters
Letters sent to New Scientist, 9 Derry Street, London, W8 5HY will be delayed

For the record

In quick crossword #172 (30 November, p 45), the clue for 7 Down should have been Rb.

The ultimate guide to skincare

Our skin may be the body's outermost layer, but its role is far from superficial. Scientists are coming to realise that it can be implicated in a host of illnesses – and by keeping it in good condition, we may be able to improve our health.

From creams to cosmetic "tweakments", mindfulness to the microbiome, over the next nine pages we examine the evidence on the best ways to safeguard your skin.

HOW DOES YOUR SKIN INFLUENCE YOUR HEALTH?

The skin is by far the body's biggest organ. Depending on your height and body mass, it covers an area of around 1.5 to 2 square metres and weighs between 3.5 and 10 kilograms – around 15 per cent of your total body mass.

Think of it as a kind of intelligent armour. It helps you sense the world around you, protects your internal organs and defends you from pathogens. This would be reason enough to take good care of it, especially because premature ageing of skin can degrade its ability to fulfil all these functions, leaving you at higher risk of infection. The latest research, however, suggests that the consequences of skin health may go much deeper.

To understand why, we need to examine its structure. Skin is composed of three layers: the outer, waterproof epidermis that is constantly regenerating; the dermis beneath, packed with fibres of collagen and elastin; and the underlying subcutis, or hypodermis, made of fat and connective tissue and filled with cavities that help to buffer the rest of the body from shock. Damage to these layers can trigger skin cells to pump out inflammatory proteins. In the short term, this results in more blood flowing to the area of injury, which can speed up healing. ›

SOFIA BONATI

Fact or fiction?

Advice on skincare is often based on anecdote rather than data, so what is the truth of some common assumptions?

Drinking more water enhances skin quality

Unknown. We should drink when we are thirsty, but the evidence that additional fluid intake brings dermatological benefits is weak.

Chocolate can cause spots

Probably true. Various studies show that chocolate (and dairy products) can inflame acne, even if you are eating an otherwise healthy diet.

ROBERT ALEXANDER/GETTY IMAGES

Poor sleep increases wrinkles

Probably true. Good sleep is associated with a more youthful appearance, while sleep deprivation can exacerbate signs of ageing like wrinkles and drooping eyelids.

We should shower less than we do

Probably true. Long showers with excessively hot water and strong soaps can lead to dry and cracked skin. Showering a few times a week may suffice. David Robson

But if high levels of inflammation are maintained over longer periods, those chemicals may build up and, with the help of a vast network of blood vessels in the dermis, spread to other organs and damage them.

Accelerated ageing

Ageing can accelerate this process. As we get older, our skin loses collagen, water and fat – making it more fragile. Worse still, many skin cells enter a state called senescence, in which they ramp up the production of inflammatory chemicals. This potentially toxic cocktail seems to amplify the risk of age-related conditions such as diabetes, heart disease and dementia. Although we don't yet have definitive proof of this hypothesis, various lines of evidence now support it. Animal studies, for instance, have shown that skin damage can trigger widespread inflammation. Researchers from the Erasmus University Medical Centre in Rotterdam, the Netherlands, meanwhile, found that whether someone's face looked older or younger than their actual age was linked to their overall risk of developing cataracts, osteoporosis, hearing loss and chronic obstructive pulmonary disease, as well as their general cognitive functioning.

In the future, we may well have "senotherapeutic" drugs to either clear away senescent cells, including those in the skin, or stop them releasing inflammatory proteins. These are still under development, but progress is promising. In the meantime, there is a host of lifestyle changes that can help us all to care for this crucial and fascinating organ. Read on to find out more.

David Robson

> *Our skin is the first organ to be affected by environmental pollution*

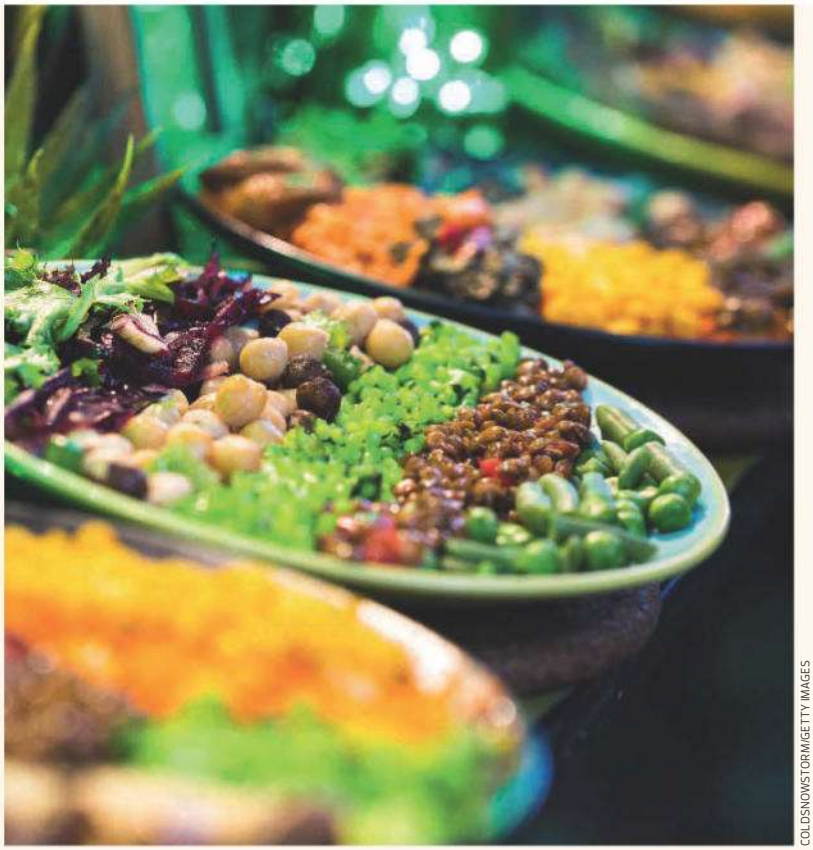
WHAT SHOULD WE BE EATING TO MAKE OUR SKIN GLOW?

Your skin is under constant assault. Exhaust fumes, cigarette smoke, particulate pollution, heavy metals and ozone can generate reactive oxygen species (ROS) that attack DNA, rupture cell membranes and unravel life's essential proteins. Perhaps the most harmful are UV rays, which generate ROS as well as disrupting DNA directly.

The human body can mop up ROS and neutralise them, but it needs molecules found in fruit, vegetables and leafy greens to do so.

Carotenoids are among the nutrients that have been most extensively studied for these benefits. These are the pigments that give the likes of pumpkins their bright colour. "They are very good antioxidants and they are particularly good at neutralising singlet oxygen [a type of ROS]," says Jean Krutmann at the Leibniz Research Institute for Environmental Medicine in Düsseldorf, Germany, who recently analysed 50 years of data from human clinical trials involving carotenoid supplements. "The carotenoids catch them and neutralise them before they can do damage."

These substances are best at protecting against longer wavelengths found in UVA light. UVA penetrates the deepest layers of the skin, generating



COLDSNOWSTORM/GETTY IMAGES

A multicoloured diet can lead to a brighter complexion

ROS that can cause skin ageing, wrinkling and cancers. Carotenoids can't prevent the direct DNA damage caused by the rays themselves though, meaning they can't be considered a replacement for sunscreen.

Good dietary sources include carrots and tomatoes. To get the greatest benefits, however, Krutmann recommends taking carotenoids as a nutritional supplement, especially if you drink alcohol, which depletes antioxidants in your skin.

Nutrients for skin

Besides carotenoids, healthy skin requires vitamin C too, found in foods such as citrus fruits. This helps by stimulating the production of collagen, the protein that gives skin its structure and firmness. Vitamin C also works with vitamin E (nuts and seeds are a good source of this) to protect natural fats known as lipids in our skin from becoming oxidised by ROS. "Vitamin E sacrifices itself, so it gets oxidised in the place of the lipids," says Giuseppe Valacchi, who researches regenerative medicine at North Carolina State University and has written a scientific review outlining the most important nutrients for skin health. "Vitamin C then recycles vitamin E to its reduced form so that it is ready to protect the lipids again."

This recycling process can take some time. Luckily, a secondary system called NRF2 – named after the protein at its centre – can kick in when the skin is under attack and ramp up the production of other antioxidants. Polyphenols such as resveratrol, found in grapes and apples, and the substance sulphoraphane, present in broccoli and cauliflower, can activate this system.

Minerals such as selenium, manganese, copper and zinc can also increase the efficiency of the NRF2 pathway, making it work faster and more efficiently. They can be found in a range of foodstuffs, including nuts, legumes, grains and – you've guessed it – fruit and veg.

Eating your greens may sound like age-old advice, but the build-up of pollution in our environment means that it has never been more important, says Valacchi. "Our skin is the first organ to be affected, so we need to take even more care of it."

Jasmin Fox-Skelly

IS SUNSCREEN NECESSARY IN THE WINTER?

Even if we live far from the equator, we are often told to apply sun protection factor (SPF) lotions year-round to protect our skin from premature ageing and wrinkles. But is this backed up by solid science?

Just 13.5 per cent of US adults use SPF creams as part of their daily routine, according to one survey. That is clearly a problem in the summer, when the sun is brightest. While we may not show signs of burning, UV rays can penetrate the deeper layers of skin and damage it. Besides contributing to wrinkles, this can lead to skin cancer – and people who wear sunscreen are at a much lower risk of this.

However, these rays are much weaker in winter at more northerly or southerly latitudes, and the benefits of SPF must be balanced against the costs. Brian Diffey, an emeritus professor of photobiology at Newcastle University in the UK, points out that wintertime use of SPF may contribute to vitamin D deficiency, for example. SPFs can also have an environmental cost, with some studies showing that they can wash into the oceans, where their component chemicals can be absorbed by corals ›

JON BOWER/ALAMY

UV exposure drops towards the poles

New Scientist audio
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and other marine life, harming them.

Diffey has used historical climate records to calculate how much UV light a typical person living at different latitudes in the northern hemisphere is exposed to every day of the year, taking into account the fact that most people living in more northerly places work indoors and spend considerably less time outdoors in the colder, winter months.

He concluded that for a person living at latitudes of 45° north and higher, which includes vast swathes of North America and Europe, almost all UV exposure comes during the summer months, making sunscreen during winter unnecessary. "There's no point using a sunscreen when it's not doing you any good, and all it's doing is potentially increasing the risk to yourself and the environment," he says.

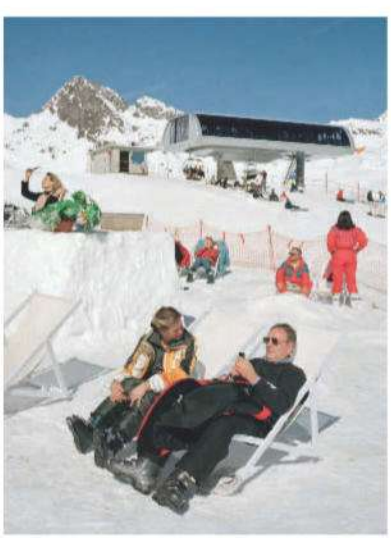
Snowballing effects

As London sits at a latitude of 51° north, Diffey argues that people there can safely go without sunscreen from October to early April. "On a typical winter's day, an indoor worker in the UK gets the equivalent of about 1 minute of summer sunbathing," he says. Residents in New York, which lies at around 40° north, can only go SPF-free from November to February, according to Diffey's calculations. And those living at latitudes of 30° north or lower should wear sunscreen all year.

While other experts agree that the potential for sun damage is much lower in the winter compared with summer, they argue that even small effects can become a problem over time. "Photoageing is a cumulative effect that adds up over the decades," says Jean Krutmann at the Leibniz Research Institute for Environmental Medicine in Germany. "So, if you use a product which provides protection against UVA and you do this every day, then by 40 you will look significantly younger than somebody who didn't do this."

Ivan Litvinov, a dermatologist at McGill University in Montreal, Canada, agrees that the benefits of using SPF in winter outweigh any potential risks. Sunlight triggers the production of vitamin D in the skin, but the amount produced at higher latitudes at this time of year is negligible, he says – and it can easily be remedied with supplements. Anyone with a family history of melanoma, with very fair skin or who is taking immunosuppressants or medications that make you more sensitive to UV light should always wear sunscreen, he advises.

"I have patients who are 104 and they're getting skin cancer, not by frying on sun loungers, but just by doing regular activities," says Litvinov. "So, if you're fair-skinned and you want to live to [that age] then, by golly, you should be more robust in terms of your sun protection measures." **JF-S**



MARTIN PARR/MAGNUM PHOTOS

The risks of winter sun exposure can add up over time

> *A cleanser, moisturiser and sunscreen cover nearly all your skin's needs*

GABBY JONES/BLOOMBERG VIA GETTY IMAGES

WHAT SHOULD WE LOOK FOR IN SKINCARE PRODUCTS?

Whether you want to brighten, firm, plump or smooth, there is an eye cream, neck cream, lip cream, face cream, serum, lotion or capsule available, for day or night use. But should you choose the one containing retinol or ceramide; enriched with green tea extract, marine collagen or pentapeptides? The choice of products, ingredients and regimes can be bewildering.

One thing that many dermatologists agree on is that it pays to keep things simple. "If you don't have time for anything else, a cleanser, moisturiser and sunscreen will cover about 90 per cent of what skin needs on a day-to-day basis," says Victoria Fu, a skincare chemist and co-founder of Chemist Confessions, a cosmetics company that says it helps consumers decipher skincare ingredients.

Although it is a good idea to cleanse twice a day, doing so in the evening is more important in order to remove the build-up of sweat, oil, pollutants,

The choice of products promising to slow or reverse ageing can be overwhelming

> *Retinoids stimulate collagen production and encourage cellular turnover*

sun cream and make-up, if you wear it. "The breakdown of those chemicals can cause a stress response in the skin, so it is important to get those things off," says Emma Craythorne, a London-based dermatologist and founder of skincare company Klira. "It is also important because our skin cells [are constantly replaced], otherwise you end up with bits of dead skin stuck to you like a crusty scale."

Expensive cleansers aren't necessary – a soap-free synthetic detergent, such as a gentle cream cleanser, will do, says Craythorne.

The big 4

After cleansing, most people will want to restore the skin's protective barrier by applying a moisturiser. A good one will contain three components: an emollient to soften the skin, a humectant to draw water in and an occlusive to prevent moisture escaping. Most brands don't provide this information on their ingredient lists, but there are websites, such as incidecoder.com, that do. You can also look out for some of the common ingredients that serve these purposes: glycerin and hyaluronic acid are humectants, ceramides and paraffin are emollients, while petroleum jelly and most oils and butters are occlusives. To slow skin ageing and reduce the risk of hyperpigmentation, in which some patches of skin darken, you should also apply some SPF (see "Is sunscreen necessary in the winter?", page 31).

Beyond these basics are active ingredients targeting specific skin concerns, including dullness, uneven texture and signs of ageing.

Deciphering claims about these ingredients can be tricky. "Every year, there are at least three more 'miracles' on the market," says Fu's colleague and fellow chemist Gloria Wu. However, in their book, *Skincare Decoded*, they focus on the "big 4" – ingredients with the strongest evidence to back up marketing claims. These are retinoids, vitamin C, niacinamide and alpha hydroxy acids (AHAs).

Whereas ingredients such as hyaluronic acid temporarily plump and smooth the skin, some of the big 4 may have longer-term health benefits. "Retinoids, for example, stimulate collagen production and encourage cellular turnover, which can improve skin resilience, while vitamin C protects the skin from oxidative damage due to environmental stressors like UV exposure and pollution, thus supporting long-term skin health and reducing future damage," says Anjali Mahto, author of *The Skincare Bible* and a consultant dermatologist at Self London, a private clinic.

Retinoids include a form of vitamin A called all-trans retinoic acid (tretinoin), which is a prescription-only medicine. This is the only cosmetic ingredient for which claims of reductions in wrinkles, sallowness and hyperpigmentation are supported by evidence from randomised clinical trials, the gold standard approach for medical matters, rather than lab-based studies or small, poorly controlled trials. However, tretinoin takes three to six months of regular use to work and can cause skin peeling and irritation, so isn't suitable for everyone. Gentler alternatives include retinal and retinol, which are converted into retinoic acid in the skin and tend to be less irritating.

Vitamin variants

Vitamin C also has variants, but most clinical studies have looked at the standard form, L-ascorbic acid. Not only does it neutralise damaging free radical molecules, including ROS, it has also been shown to reduce uneven pigmentation, brightening the skin. L-ascorbic acid is unstable in water, light and air, so products containing it should be kept in a dark cupboard and not stored for too long. It may also irritate sensitive skin, making vitamin C derivatives such as sodium ascorbyl phosphate or ascorbyl glucoside a better option for some.

Then there is niacinamide. Like vitamin C, it has brightening properties and may help to regulate oil production. It may also strengthen the skin's ability to act as a barrier, reduce inflammation and improve our outer layer's natural defences over time, says Mahto. However, the evidence for these benefits is weaker than that for vitamin C or retinoic acid.

The final class of ingredient in Fu and Wu's "big 4" are AHAs. These acids don't necessarily improve skin health, but by increasing the rate of skin turnover and shedding, they may improve its appearance. "The rate at which these dead cells shed can really slow down with age, and when AHAs have been clinically tested at higher levels, they've been found to diminish the looks of fine lines and pigmentation," says Wu.

A lot of products also boast about containing collagen, but when you apply this to your skin, it largely functions as another moisturising ›

agent, rather than boosting levels of this structural protein. "It is a humectant, so it can help to keep skin hydrated, but collagen is a really big molecule, so for the most part, it doesn't really replenish your collagen like the [labels] suggest," says Wu.

Tempting as it may be to search for a single product that contains multiple active ingredients, this is unwise. "Each of these molecules has their quirks, and trying to formulate all these together wouldn't be ideal for some of them. For example, ascorbic acid has a very low pH, whereas retinol doesn't like to be in a low pH," says Fu.

Day vs night creams

Most anti-ageing creams don't list the amount of each active ingredient they contain, which makes it hard to assess their likely efficacy. Mahto's advice is to use a gentle cleanser and sunscreen in the morning (which will also function as a moisturiser), and then a make-up remover, cleanser and moisturiser in the evening. If you want to experiment with active ingredients, she suggests using a serum, as these tend to be more concentrated and penetrate the skin more effectively than creams, "but add only one new product at a time and pay attention to how your skin responds".

You may not need to buy separate products for day versus night, either, provided your morning routine includes an SPF, says Emma Wedgeworth, a dermatologist and spokesperson for the British Skin Foundation, a medical charity. "I will always use separate sun protection and active ingredients, so I use the same moisturiser morning and evening, just with different supporting products," she says.

Linda Geddes

> *Serums may penetrate the skin more effectively than creams*

DO 'TWEAKMENTS' IMPROVE OUR SKIN HEALTH?

Our skin inevitably loses some of its elasticity as we age. In the past, the main weapon against the wrinkles and sags – for those who could afford it – was to go under the surgeon's knife. Today, there are a wealth of less invasive alternatives that promise to firm up and rejuvenate our skin – everything from Botox injections to devices that blast light or ultrasound into the skin, and even "vampire" facials, where blood extracts are injected into the face.

Given that healthy skin brings wider health benefits, do these "tweakments" rejuvenate from the outside in? "The question is, is this just vanity or are you doing anything that's going to help your future self?" says dermatologist Clare Kiely at Guy's and St Thomas' Hospital, London. "It depends on the type of treatment."

Ageing comes with many transformations, but the primary cause of our wrinkles is a reduction in collagen and elastin, proteins that provide firmness and elasticity. Treatments such as Botox – injection of botulinum toxin to prevent muscles contracting – will do nothing to stop these changes, though they can be an effective way to prevent frown lines when injected into certain facial muscles. Likewise, injections of gel-like substances called dermal fillers beneath the skin can smooth wrinkles and add volume to sagging tissue, but don't address the underlying structural changes, and come with risks.

Help could be at hand by other means, however. In recent decades, a number of laser, radiofrequency, ultrasound and intense pulsed light devices have been introduced that can ostensibly restore that youthful glow. Developed from treatments to promote wound healing and reduce scarring, these technologies all involve waves of energy penetrating the outer layers of the skin to heat it from within.

"If you heat the skin up enough, you basically stimulate a kind of a wounding response," says Kiely, which then spurs the body to produce collagen and elastin to heal the damage. "So you're playing with the body's ability to repair itself."

Tiny injuries

Another therapy, microneedling, in which tiny needles puncture the skin to create micro-injuries, is also based on these wound-healing principles.

High-quality, large-scale studies in this field are sorely lacking, but evidence suggests these treatments can boost collagen and elastin levels, with noticeable effects on skin appearance. However, they need to be regularly repeated and the long-term benefits are unclear. "The heat energy basically causes a tightening of the skin, but whether in the long run they're beneficial, we don't know," says Kiely, who is also founder of the skincare company The Skin Diary.

An ideal treatment would also rejuvenate individual skin cells so that they resemble younger versions of themselves, through other changes

RICK EGLINTON/TORONTO STAR VIA GETTY IMAGES

ANCHIY/GETTY IMAGES

Cosmetic treatments (above) don't always improve underlying skin health; microneedling (below) may trigger a wound-healing response that encourages collagen formation

in their biochemical processes. The most promising results so far come from research led by Anne Lynn Chang at Stanford University, California, on the effects of intense pulsed light treatment on the skin of five women aged over 50. The treatment resulted in demonstrably less wrinkled skin, despite no increase in collagen or elastin levels, with the researchers reporting that "'rejuvenation' at a molecular level has also occurred, with a number of genes linked to the aging process being altered in expression after treatment to more closely resemble young skin".

Search online and it is easy to find more outlandish ideas. A case in point is vampire facials, the colloquial term for platelet-rich plasma injections, which have garnered much recent media attention. In these, blood is taken from the arm and treated to extract components called platelets, which are then injected into your face to supposedly reduce wrinkles. "Despite the hoopla, there's little evidence to show that it works – or doesn't work," is the conclusion of the American Academy of Dermatology Association.

For now, the effectiveness of all these tweakments is rather vague. It is possible that some light or laser treatments can improve the strength of our skin, at least temporarily. But whether this can turn back our cells' molecular clocks remains to be proven.

Alison George

> *Despite the hoopla, there is little evidence that vampire facials do or do not work*

HOW DOES OUR MENTAL STATE INFLUENCE OUR SKIN?

Even if you don't wear your heart on your sleeve, your skin may betray your mental state.

"There is a very strong connection between the brain and skin, and a connection between stress and skin diseases," says Gil Yosipovitch at the University of Miami, Florida. This is evident, he says, in his encounters with patients: "I always ask, for instance, does anything aggravate your itch? And many patients will tell you it's stress." This observation is also borne out in clinical studies.

On a physiological level, it all comes down to hormones. Psychological stress, whether it be chronic or acute, causes our bodies to produce hormones called glucocorticoids, which keep us more alert and provide energy for the fight-or-flight response in dangerous situations. But they also harm the skin in two ways.

First, they can diminish the functioning of the epidermis. This top layer of skin locks in moisture and serves as the first layer of defence between our bodies and the environment. Consistently high levels of some of these hormones, like cortisol, can also cause inflammation. Second, glucocorticoids decrease the production of antimicrobial proteins in the skin.

The combined effect is skin that is dry or inflamed, is prone to infections and heals more slowly, leading to a heightened susceptibility to clinical skin conditions. "There is a direct connection between stress and a tendency to get sick," says Peter Elias ›

THOMAS LOHNES/GETTY IMAGES

Academic anxiety can exacerbate conditions like acne

at the University of California, San Francisco.

In a review of 21 studies, Yosipovitch and his colleagues found that this is true across various sources of stress, ranging from marital strain to insomnia and isolation. A study by Yosipovitch and others, which examined a sample of 94 secondary students in Singapore, is a case in point. They found that, on average, the adolescents' acne was 23 per cent more severe and inflamed right before an important exam, compared with when they had just returned from a school vacation.

Stress test

Mental distress can also aggravate skin conditions in a more mechanical way – through scratching. For example, Yosipovitch and his colleagues studied how people with atopic dermatitis, or eczema, which makes the skin dry and itchy, respond to a stress test. Here, study participants had to deliver a short presentation as part of a mock job interview, then quickly complete a mental arithmetic task. "The itch intensity was not affected, but the amount of scratching the subjects did was way above [their baseline] during this stressful event," says Yosipovitch. Consequently, "a vicious itch-scratch cycle" can take hold and exacerbate the skin conditions of a patient, he says.

The connection between mental health and skin may offer new avenues for treatment. A recent review examined the available evidence for the benefits of meditation and mindfulness for psoriasis. Of the six randomised controlled trials considered, five reported significant improvements in symptoms after eight or 12 weeks of practice. Other studies indicate that relaxation techniques, such as progressive muscle relaxation, where a person tenses and relaxes one muscle group at a time, are beneficial for people with chronic itch and that mindfulness training benefits people with eczema.

In view of this increasing evidence, dermatologists should be more aware of their patients' mental health, says Yosipovitch. This isn't yet common practice and diagnostic tools that are used in research, such as questionnaires, typically aren't used in busy dermatology clinics.

There are still open questions about how exactly our skin "feels" what we feel. "The skin makes almost everything that's also made in the brain. It makes cannabinoids, it makes opioids, it makes all kinds of agents that can potentially be released in response to stress. But which among them are the major players is not yet clear," says Elias. Future studies could elucidate this – and offer new routes towards better skin health in the process.

Karmela Padavic-Callaghan

HOW CAN WE BOOST THE SKIN MICROBIOME?

Look under the microscope at any square centimetre of human skin and you will find it teeming with bacteria, fungi, mites and viruses. It might sound yucky, but your skin's microbiome is an important defence against invading pathogens.

"Because there are all these bacteria already there, it's quite hard for a pathogen to get a foothold," says Catherine O'Neill, a dermatologist at the University of Manchester, UK, and chief science officer of AxisBiotix, a company that offers skincare products based on microbiome research. "Bacteria can also wage warfare on each other by secreting different chemicals that inhibit the growth of pathogens."

The skin microbiome, together with the gut microbiome, also helps train our immune system during childhood, teaching it to attack pathogens and ignore harmless stimuli. This could explain why people who have a greater diversity of skin bacteria are less likely to have allergies.

MICHAEL ZEGERS/IMAGEBROKER.COM GMBH & CO. KG/ALAMY

Beneficial skin bacteria could also be the key to maintaining a smooth, wrinkle-free appearance. Our skin is like a fortress constructed from layers of skin cells packed together. In between the cells are lipids that keep the skin supple and plump, and certain bacterial species help to replenish those stores.

"*Cutibacterium* stimulates the skin to produce sebum, which protects the skin, reduces water loss and increases hydration," says Holly Wilkinson, who studies wound healing at the University of Hull, UK. *Staphylococcus epidermidis* and *Streptococcus thermophilus* can produce ceramides, meanwhile, which can also reduce water loss and protect the skin barrier.

The skin's allies

As we age, the delicate balance of the skin microbiome can be disrupted, as the "good" bacteria that protect us from infection and keep our skin hydrated are replaced by harmful, pathogenic species. This state of skin "dysbiosis" has been linked to acne, rosacea, psoriasis and eczema, as well as problems with wound repair.

Given these benefits, it should be no surprise that scientists are looking for ways to keep our skin's allies happy. One idea is to use prebiotics, or nutrients that feed and encourage the growth of good bacteria.

These include inulin, a dietary fibre found in asparagus and bananas, which can be eaten to support gut health or applied topically to the skin. In addition, scientists are exploring whether slathering live good bacteria such as *S. thermophilus*, together known as probiotics, directly on the skin could allow them to become established there.

Making a working probiotic is easier said than done, however. "It's technically extremely challenging just to keep the bacteria alive," says Bernhard Paetzold, co-founder and chief scientific officer of S-Biomedic, a company that aims to treat conditions by restoring the skin's microbiome.

The third idea, known as postbiotics, involves applying the products of beneficial bacteria to the skin as a supplement. Some researchers advocate for using sphingomyelinase, an enzyme produced by bacteria like *S. thermophilus* that boosts production of ceramides, as such a treatment.

Ongoing human clinical trials are testing the effects of prebiotics, probiotics and postbiotics on inflammatory skin conditions. "Their initial findings are certainly promising, but we need larger-scale studies to provide convincing evidence for their wider use," says Wilkinson.

Mud therapy may help to replenish the beneficial bacteria in our skin microbiome

> *People who have a greater diversity of skin bacteria are less likely to have allergies*

STEVE GSCHMEISSNER/SCIENCE PHOTO LIBRARY

The skin microbiome contains around 1000 species

There may be other means of tending your skin microbiome. Gardening has been shown to increase the diversity of bacteria on the skin, albeit temporarily: most new microbes fail to take root and disappear after just 12 hours.

Gut-skin axis

Another option could be to receive mud therapy at a spa. A 2018 review of five previous studies concluded that, in many cases, natural muds were effective at wiping out pathogenic strains of bacteria while leaving beneficial ones unharmed. It is important to note, however, that many of the studies weren't conducted in humans.

You may have read that washing too frequently can disrupt the skin microbiome, but the evidence is contradictory, so there may be no need to forgo your cleansing routine on account of your resident bacteria.

Perhaps the easiest way to boost your skin microbiome is to eat healthily (see "What should we be eating to make our skins glow?", page 30). We now know that the bacteria in your gut can influence your skin health through what is known as the gut-skin axis. This might explain why diets high in unhealthy foods, like fast food, may trigger acne, while eating lots of fibre can alleviate symptoms of eczema, at least in mice. "As ever, a healthy diet with fresh whole foods is always the answer," says O'Neill. ▮ **JF-S**

Backwards computing

To curb AI's extraordinary energy demands, we need computers that run in reverse, says **Karmela Padavic-Callaghan**

SUPERTOTTO

IMAGINE taking a hammer to your laptop. You smash it apart and shards of plastic, batteries and circuit board go flying. It would be an act of vandalism, a shocking waste of money and resources, so much so that it sounds absurd. But the truth is that, every time we use a computer, we are dealing with a machine that is, at the fundamental level, even more wasteful than this.

It all goes back to a decision made decades ago about the deep workings of computer logic and how these machines delete data, a process that inevitably produces a large amount of waste heat. For a long time, we have muddled through with wasteful computers. But with the rise of artificial intelligence, which has pushed the power demands of computing to new heights, this seemingly inconsequential decision might be about to bite us. We may need to redesign computing from scratch.

Thankfully, we know exactly what to do. It involves a trick that might sound a touch unlikely: getting processors to do everything twice, once forwards, then in reverse. "Reversible computing can be so much more energy efficient than conventional computing, and it's potentially the way we should have originally built computers," says Hannah Earley at UK-based reversible computing company Vaire Computing.

The increased energy efficiency is the result of a thermodynamic trick that we have known about since the 1970s, but was never put into use because of the relentless improvements in traditional computing. Now, though, it may be reversible computing's time to shine. If it can avoid computers' constant, built-in waste, it may be crucial for reaching a future where advanced computing and AI improve our experience of the world without simultaneously wrecking it.

AI is already part of our lives. Two years after it launched, ChatGPT and its many cousins are seemingly everywhere, answering questions, writing articles, designing chips and even helping surgeons suture wounds. Their effect on how we work is becoming hard to ignore, as is their staggering environmental impact. ChatGPT's daily power usage, for instance, is equivalent to that of nearly 180,000 US households, and the energy demands of AI are increasing daily, straining the electricity grid.

As most of the energy currently used by AI comes from fossil fuels, meeting this demand is increasing greenhouse gas emissions. To accommodate the growing demand for AI, companies are building more of the data centres needed for this technology, and these construction projects further add to AI's carbon footprint. Data centres and cloud computing, which are used for several services including AI, already account for as much as 2 per cent of global greenhouse gas emissions, a larger share than the whole aviation industry.

Proposed solutions to this growing problem vary from the plausible to the downright wacky. Some companies are resolving to use more renewable energy, others are betting on the rise of nuclear power. More extreme ideas include cooling data centres not with air conditioning, but by putting them underwater – or even in space.

Yet none of these ideas lowers the amount of energy that computers need to run programs or software, they merely find new ways to supply it. "There is a huge gap between what software wants and what the hardware can really do," says Aida Todri-Sanial at Eindhoven University of Technology in the Netherlands.

The main reason why AI is so energetically costly is simple: standard computers use energy extraordinarily inefficiently. And they are inefficient because they are constantly erasing information. Though it may seem

trivial, this action brings computers right into the crosshairs of the laws of thermodynamics, fundamental principles dealing with energy, heat and entropy, or the measure of disorder that also determines which processes can be reversed.

To be effective, erasing information ought be an irreversible process – it only makes sense if you cannot restore the erased bits – but strictly speaking the laws of thermodynamics forbid that. They stipulate that information can't disappear, it must go somewhere. So when a bit is erased, although the computer makes sure the information cannot be practically recovered, it is impossible to completely destroy it. Instead, the information deteriorates into randomness, or thermal noise, which increases the computer's entropy and makes it heat up.

> "Reversible computing is potentially the way we should have originally built computers"

Today's computers constantly erase information. At the level of hardware, each computer program becomes a sequence of operations on electrical signals – a bunch of tiny electronics directing electrons where to go and what to do. The most basic operations are represented by so-called logic gates such as "AND", which takes the input signals A and B and outputs their sum, A+B. As soon as A+B is fed into the next gate, A and B are erased. All logic gates erase information in this way, so heat production is baked into the very building blocks of any computation – computers are heat-producing machines as much as they are computational devices.

Pushing the limits

In fact, computers expend far more energy on making heat than on doing calculations. In 1961, IBM's Rolf Landauer determined how much energy a device has to spend to erase a single bit, the so-called Landauer limit. If today's best computers really used just that much energy every time they erased a bit, they could be powered by a few milliwatts of electricity, thousands of times less than a typical light bulb. In reality, they are much worse than the idealised situation Landauer envisioned and operating them requires dozens of megawatts, or the equivalent of millions of light bulbs.

Researchers who followed in Landauer's footsteps suggested a way to avoid this remarkable inefficiency: create a computer that doesn't just forego erasing information, but where all processes are completely reversible. While thermodynamics dictates that any effectively irreversible process be accompanied by an increase in entropy – just as happens in conventional computers – reversible processes leave entropy unchanged, so little energy is wasted as heat. If reversible computers could eventually run AI programs, this would be at a much lower energy cost, making their hunger for power more manageable with existing energy resources.

Building these machines, however, requires radically unconventional computer chips and a computing philosophy that is far from intuitive for traditional programmers. The key intervention is to shift how we use the logic operations that underlie computer programs.

Consider again the AND logic gate that ›

takes inputs A and B and outputs A+B. In a conventional computer, A and B are erased, but in a reversible computer, they must be stored in some memory to avoid the energy cost of deleting it. Landauer was worried that any effort to sidestep that cost would eventually mean running out of memory, but researchers have since developed a workaround that requires every calculation to be performed twice, first forwards, then backwards. This is because any extra memory that must be used during the forwards operation gets freed up once the same operation is run in reverse.

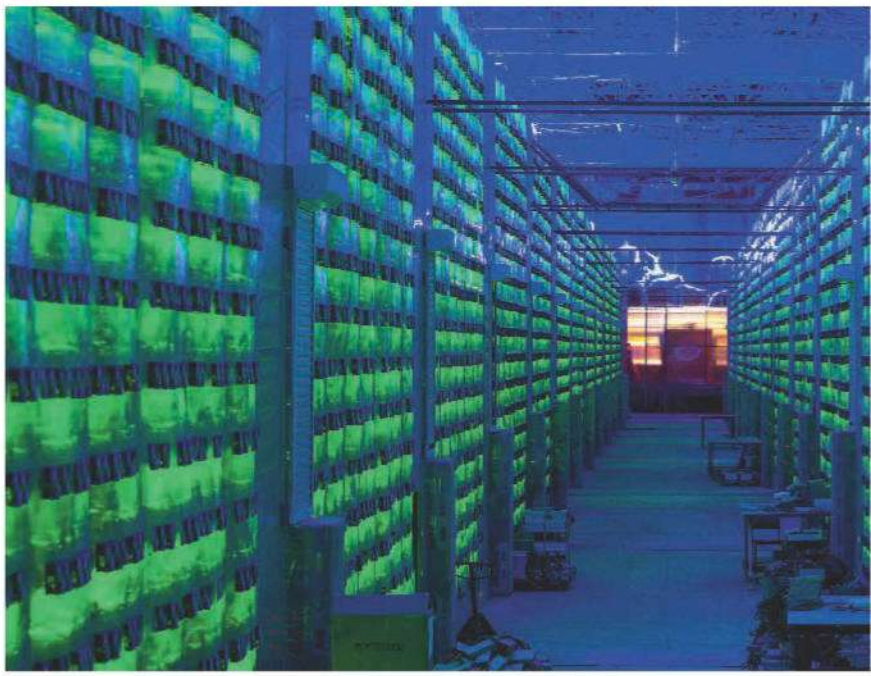
Though it might seem that doubling the number of operations would also double the computer's energy consumption, that isn't how it plays out. Neither direction of operation involves erasing information, nor any other irreversible process, so the added backwards step doesn't incur any notable energy costs. Given a bit more work, the stored data can even be reused in more complicated operations rather than the practically essential but computationally useless task of running the same operations in reverse.

Reversible computers take advantage of thermodynamic quirks in one other way: they move electrons, which is the physical process underlying everything a computer does, more slowly than traditional computers. This means that, viewed as a physical system, a reversible computer is never too far from equilibrium, with fewer electrons being blasted back and forth. It is therefore less likely to expend lots of energy returning to its base equilibrium state – again reducing waste.

"We don't know of any fixed limit to the amount of energy savings that you can get with reversible computing. Ten times, a hundred times, a thousand times – in theory, it just keeps going," says Michael Frank at Vaire Computing. Though Frank and others at Vaire have been interested in reversible computing for more than 30 years, with the new computing challenges posed by AI, along with the slowdown in traditional computing's improvement, Vaire is the first company in decades that stands a chance of making them commercially viable, says Earley..

In theory, we could have built computers this way to begin with. "We're very fortunate in how much stuff has been done before. For the most part, we are facing more of an engineering problem than a science problem," says Earley.

In 1973, Charles Bennett at IBM proved it is theoretically possible to construct fully reversible computers that could perform any computation that a traditional computer could. So, how did we end up with lossy, irreversible computers?



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Frank says the answer is easy: conventional computing kept improving so quickly that it felt unrealistic to try to compete. "You can't really hope to catch up and surpass a very fast-moving industry where a lot of resources are being poured into advancement," he says.

Totally steamrolled

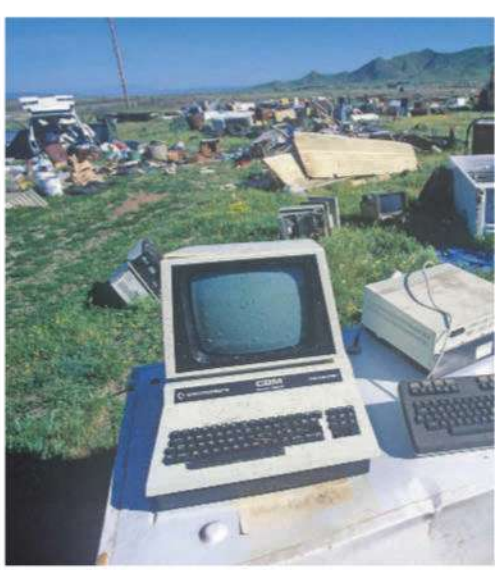
Gavin Crooks at Normal Computing, a US-based start-up, is more direct: "Whenever a new idea for unconventional computing came around in the past, conventional computing steamrolled it."

Traditional computers owe this success largely to Moore's law, which postulates that microchips can be miniaturised, and the power of computers thus increased, exponentially quickly. Although it remained an accurate conjecture for years, it started to falter about two decades ago. "We're getting to the point where there's diminishing returns from further miniaturisation and we're starting to approach limits on the efficiency of chips that relate to very fundamental physical phenomena," says Frank.

He was part of a Massachusetts Institute of Technology team that designed and constructed the first fully reversible processor in the late 1990s. This chip, and the ones that followed, mostly served as proof of concept that a reversible computer could be built – but now, he and his colleagues are betting that such machines can compete with traditional computers. Vaire expects its first commercial chips to come to market in 2027.

To truly compete will require a transformation in computer chips and

"There will be an avalanche of special chips, they'll help each other out"



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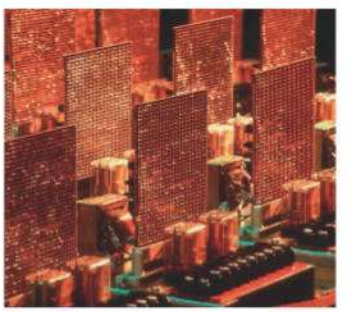

ERICH HARTMANN/MAGNUM PHOTOS

Computer chips (near left) and data centres (far left) demand huge amounts of energy, much of which currently comes from fossil fuels

the language used to program computers. "We need to rethink what computing really is," says Todri-Sanial.

Jacques Carette at McMaster University in Canada says that a fully logically reversible computing language would look "extremely foreign" to a conventionally trained software developer and that it would be a challenge to build such a language from scratch. Earley and the Vaire team want to avoid this as much as possible. They are working on an interface that would allow coders to use the company's future chips without such a steep learning curve by tweaking existing conventions, instead of inventing an entire new computing language.

The computers in this junkyard were wasteful when they actually worked

"We want to make sure that, from the outside, there's no friction to using our technology," she says. "The goal we are trying to hit is really making it look as normal as possible."

When it comes to hardware, the team has been working on improving a component called a resonator. Within chips, electrical signals are produced by the flow of electrons, and they would flow in and out of this new version of the resonator much more slowly than is common in conventional ones. Slowing this flow would keep the computer from "noticing" that the electrons are moving, so heat isn't shuffled around and wasted in response to the change to bring the computer back to equilibrium. This is crucial to allowing computations to then be run backwards. Earley says that Vaire patented a new kind of resonator just last year that will make its chips much more practical than any of the prototypes from the 1990s.

"The tools that [researchers] were using were in a more primitive state back then and chip design was a more manual, labour-intensive process," says Frank. "Modern tools can save us time, but some of those tools also have to be rewritten for reversible design. So, at Vaire, we're sort of building the tools we need as we go."

Despite all the work that has been done already, making reversible computer chips suitable for commercial production in existing factories and viable as products that computing facilities could slot into their workflow will require a lot more computational development in a compressed amount of time.

And time may be the biggest issue. "It's great to see attempts to develop new technologies to deal with the energy consumption of computing, but the challenge will be how quickly it can be brought to market, because the demand... is happening right now," says David Mytton at the University of Oxford. In addition, Mytton says that efforts are under way to improve traditional software and hardware too.

While Vaire is the main player in reversible computing, it isn't the only unconventional computing game in town – a handful of other start-ups are working on other new types of computer chips. Although Normal Computing's chip also takes advantage of our understanding of thermodynamics, its operations aren't reversible. Instead, it uses naturally occurring fluctuations in chip temperature to run calculations. A possible input into this chip may be a change in temperature of one of its components, and the output is read out by analysing the thermodynamic properties of the equilibrium state that the chip reaches after some time.

This process can't be run backwards, but because the computer always naturally moves towards equilibrium without energy having to be spent, it also promises energy savings. Normal Computing says the chip will be well suited for a type of algorithm called probabilistic AI, which could be used for some of the tasks currently tackled by more conventional AI, such as generating text and images. Since starting work less than a year ago, Normal Computing has produced its first working chip and is now developing more advanced hardware and building out the theory for its software, also on a compressed timescale.

Crooks believes that now the AI energy crisis has put unconventional computing in the spotlight, there is room for all of these solutions. "In five years, there may be a lot more diversity, a Cambrian explosion of niche ideas," he says. Patrick Coles, also at Normal Computing, agrees: "There will be an avalanche of special chips. Instead of competing, they'll help each other out." Each chip will fill its own unique niche, he says.

Getting there won't happen overnight, he concedes, saying it will be a "long, hard haul". But he, Earley and the rest of the Vaire team are eager to do the work. "I always tell people reversible computing is not an easy way forward, but it's the only way forward," says Frank. ▮

Karmela Padavic-Callaghan is a physics reporter for *New Scientist* in New York

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Stargazing at home

Eyes on the skies

From auroras to partial eclipses of the sun, **Leah Crane** is planning out the astronomical events she will be watching next year

Leah Crane is a features editor at *New Scientist* based in Chicago. You can reach her at launchpad@newscientist.com

AS THE new year approaches, I like to take a moment to mark down the things I am looking forward to – whether that be a big trip, seeing an old friend or simply experiencing summer warmth again (in Chicago December, that last one feels particularly distant). My stocktaking includes the big astronomical events I will be watching next year, so I thought I would share some of what I am excited about for 2025 with you.

First off, I have high hopes that the coming year will see more nights of astonishing auroras. Having only seen the aurora borealis once in my entire life before this year, 2024 was a bonanza, and hopefully that will continue into 2025. We are still right in the middle of the current 11-year solar cycle – in fact, activity is expected to reach a maximum mid-2025 – so it is fair to expect there will be more gorgeous light shows, like the one seen here in Alaska in 2024, to come.

TOM WALKER/ALAMY

I am also a particular fan of meteor showers. There is something about finding a dark spot and just lying there for a while watching the sky that is deeply relaxing. This year's best meteor shower in the northern hemisphere is expected to be the Geminids, which don't happen until December but promise upwards of 100 meteors per hour at the shower's peak mid-month. The Perseids in August should also be impressive. There will be fewer meteors and the glare of the moon will hide some of them, but that's the shower I tend to have the best luck with.

While both of these meteor showers will be visible in the southern hemisphere too, they will be far less impressive there. Instead, I would look out for the Eta Aquariids, which will peak in the first week of May with up to 40 or so meteors per hour. This isn't quite as dramatic as the northern hemisphere meteor showers – just bad luck as far as where in Earth's atmosphere the showers occur – but it should still be great.

The coming year is also a fun one if you love planets. Starting in January, Mars will be in opposition, meaning that Earth is directly between Mars and the sun. Opposition is typically one of the best times to observe a planet, because it is close enough to Earth to appear relatively big and bright in the sky, and the whole disc of the planet is illuminated by sunlight. Saturn and Neptune will reach opposition in September, and Uranus in November.

Finally, there are two solar eclipses in 2025, both partial (we will have to wait until 2026 for the next total solar eclipse, sadly). On 29 March, a partial solar eclipse will pass over Canada and parts of northern Europe, and then, on 21 September, another will be visible from New Zealand and Antarctica.

As for me, I will continue to look up every night the sky is clear, watching for auroras, meteors and the same old familiar stars. Happy New Year! ▮

Stargazing at home appears monthly

Next week
Mathematics of life

These articles are posted each week at newscientist.com/maker

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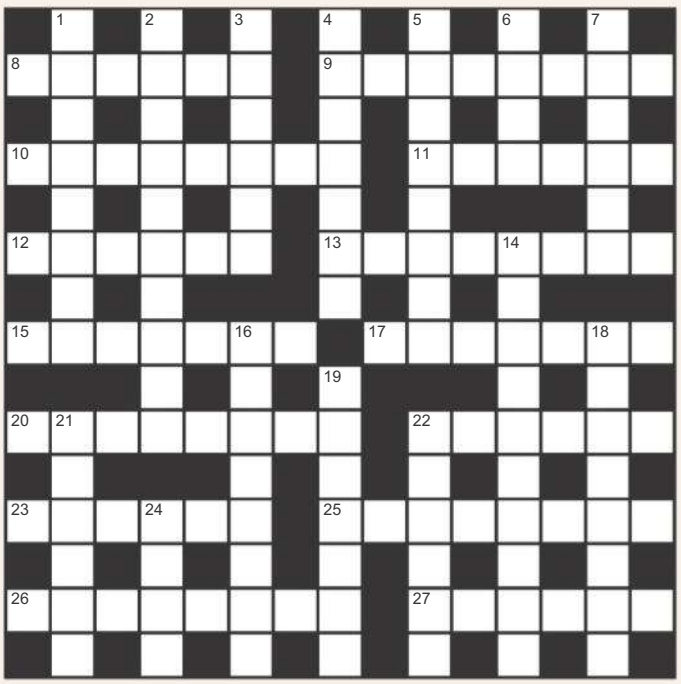
Quick crossword #173 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

8 Ab or delt, say (6)
9 Cosmos (8)
10 Taxonomic group (8)
11 Ancient plant genus (6)
12 Metal disc with a hole for a bolt (6)
13 Tibia (8)
15 Mammals in the family Leporidae (7)
17 See 24 Down
20 At (8)
22 Basic salt (6)
23 $2^4 \times 5$ (6)
25 Intestinal parasite (8)
26 Screw fastener (8)
27 Call on the telephone (4,2)

DOWN

1 Animated sci-fi series devised by Matt Groening (8)
2 Fear of heights (10)
3 Conifer native to the Himalayas (6)
4 Sugar, $C_{12}H_{22}O_{11}$ (7)
5 Bird in the tyrant flycatcher family (8)
6 Average (4)
7 Equiangular polygon (6)
14 Rare and unpredictable events (5,5)
16 Three-wheeled conveyance (8)
18 Abrupt state of confusion (8)
19 Dizziness, often associated with 2 Down (7)
21 Curve winding away from a centre (6)
22 A (6)
24/17 John ___, English X-ray pioneer (4-7)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #282
set by Bethan Ackerley

1 The face of the Great Sphinx of Giza in Egypt is thought to resemble which pharaoh?

2 The closing of a plant's leaves or petals in response to darkness is an example of which phenomenon?

3 How many extant species of kiwi birds are there?

4 Which of the following NASA astronauts wasn't a member of "The Fourteen", the third group of astronauts the agency selected: Neil Armstrong, Buzz Aldrin or Gene Cernan?

5 In what year were neon, krypton and xenon discovered?

Answers on page 47

BrainTwister
set by Katie Steckles

#53 Dividing digits

The number 1 has one digit and is divisible by 1; 12 has two digits and is divisible by 2; 123 has three digits and is divisible by 3.

Which new digit (not already used) can be added to the end of 123 to make a four-digit number that is divisible by 4?

How far can you extend this number by adding unused digits to continue the property of divisibility by the number of digits?

Can you find a way to arrange the digits 0-9 into an order for which the whole number is divisible by 10, and as you remove digits from the end it continues to produce numbers that are divisible by their number of digits, all the way down to 1?

Solution next week

Scaling it up

Why do we only use 12 notes in Western music?

Richard Ellam
Bristol, UK
Notes with frequencies that are in simple whole-number ratios, like 1:2, 2:3 or 4:5, sound good when played together. This is the basis of musical harmony. After unison (1:1) and the octave (2:1), the next most harmonious interval is 3:2, known as a perfect fifth.

Starting at any (low) frequency, you can construct a series of tones, each a perfect fifth (3/2 the frequency) higher than the one below. The twelfth tone in this series sounds like a (much) higher version of the starting tone, because it is just over seven octaves higher in pitch.

For example, in modern orchestral pitch, we define the A above middle C (A4) to have a frequency of 440 hertz. The A above this (A5) has a frequency of 880 Hz, and the A below middle C (A3) has a frequency of 220Hz. If we set up a chain of notes, each having a frequency of 3/2 that of the previous note we find that, when we get to the twelfth note, it has a frequency that is just under 130 times the frequency of our starting note ($(3/2)^{12}$ = 129.75). The frequency ratio of seven octaves is 2^7, which is 128, so our twelfth note is just over seven octaves higher than our starting note.

"Indian and other cultures quite happily use microtones, but Western music is generally unwilling to do the same"

If we now divide the frequencies down to bring all twelve tones within about one octave we find that the frequency of the twelfth tone is 129.75 ÷ 64 = 2.027 times our starting note. This is close enough to the 2:1 ratio that it sounds like the octave of the starting note, even though it isn't quite in tune.

So, in practice, we set up our musical scales so that the octaves are exactly in tune, and fudge the rest depending on what we want to achieve.

In particular, modern Western instruments are mostly tuned to "even temperament", where the frequency ratio of successive semitones is defined as being the twelfth root of two. This makes the frequency of each ascending semitone just under 1.06 times the one below, and the frequency ratio of any two notes an octave apart is exactly 2:1. Such a scale is actually very precisely out of tune, but the errors are too small to be readily noticeable. Any problems this causes are far outweighed by the advantages of being able to play "in tune" in any key.

Guy Cox
Sydney, Australia
The fundamental unit of music is the octave – ratio 2:1. But to make music, we have to divide the octave up into divisions that are still harmonically related.

The earliest of these is the pentatonic scale, where it is divided into five. But in medieval times, musicians wanted to go further and divided the octave into eight unequal notes (hence the name octave). There were different versions, called modes. These were originally for monophonic music (plainsong) but by the Renaissance it was clear they worked for complex polyphonic music. In this context, semitones sometimes needed to be added for effect. So we ended up with 12 notes, but they weren't the equal 12 we know today.

By Baroque times only two modes – which we now know as major and minor – were in use but musicians wanted to be able to use them in any key, hence the development of "temperaments". That led to our current equal-temperament tuning where every note is a bit off but they all work together. So, 12 equal notes in the octave.

But what about smaller intervals? In Indian music they are a major part of the performance. In the early 20th century, the composer Alois Hába wrote some hauntingly beautiful music in the "sixth tone" system – dividing the octave into 36 parts. We hardly ever get to hear Hába's music today – maybe because it is fiendishly difficult to perform!

Simon McLeish
Lechlade, Gloucestershire, UK
Indian and other cultures quite happily use microtones, but Western music is generally unwilling to do the same. There are exceptions, in modern music and where music of other cultures is influential (the jazz and blues traditions are probably the most familiar to the average Western music listener). At least part of the reason this is the case is tradition, familiarity and convenience. The piano is still a dominant instrument in Western music, and it is firmly rooted to the equal-temperament 12-note scale.

Even before the introduction of equal temperament, though, Western music was wedded to 12 notes, when taken in scales of eight notes. This is probably related to the dominance of Greek philosophy, which derived from Mesopotamian music. Grecian culture was immensely prestigious, and ideas about music attributed to Pythagoras became the basis of Western music, with the idea of modes (what you get if you use a scale of eight

FOTOSTORM/GETTY IMAGES

This baby is tired and needs to go to sleep, but will not be persuaded of this necessity

This week's new questions

Time for bed **Why are human babies so reluctant to go to sleep?** ***John Leonard****, Canberra, Australia*

Amo amas amat **I can see how different grunts could come to mean "bear", "deer" or "run". But how do grammatically complex languages get their cases and declensions?** ***Peter Borrows****, Amersham, Buckinghamshire, UK*

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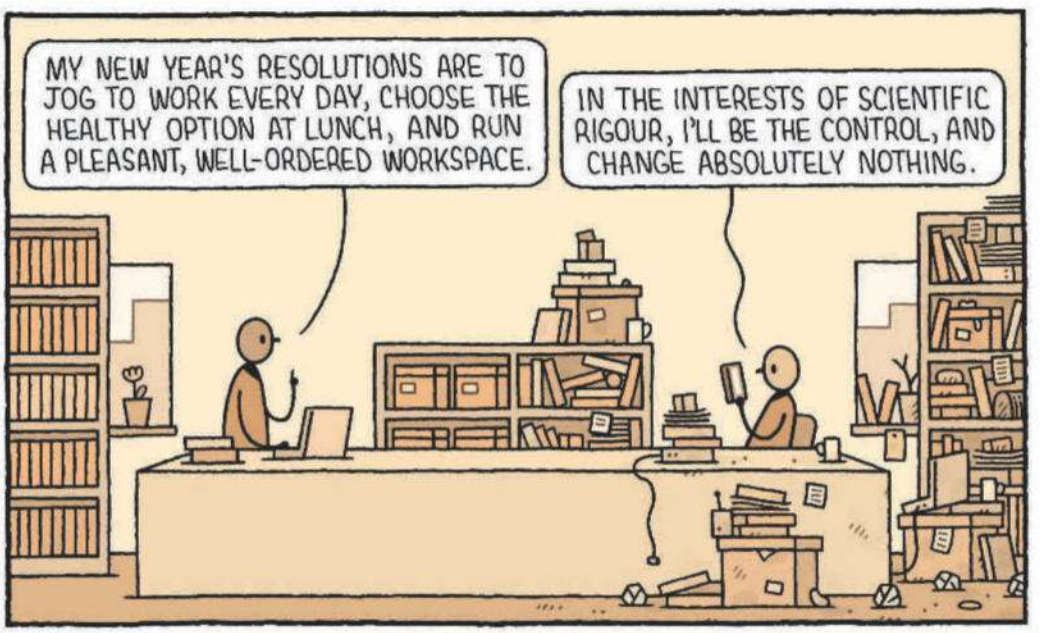
MY NEW YEAR'S RESOLUTIONS ARE TO JOG TO WORK EVERY DAY, CHOOSE THE HEALTHY OPTION AT LUNCH, AND RUN A PLEASANT, WELL-ORDERED WORKSPACE.
IN THE INTERESTS OF SCIENTIFIC RIGOUR, I'LL BE THE CONTROL, AND CHANGE ABSOLUTELY NOTHING.

consecutive white notes on a piano, which are still given Greek names, such as Mixolydian, which starts on G and then goes up in sequence G, A, B, C, D, E, F, G).

End of an era

When I die, what happens to my microbiome?

Luce Gilmore
Cambridge, UK
The fate of one's post-mortem microbiome is chaotic and messy. Most of the microbiome resides in the gut, and the gut is quite anoxic, so one's ceasing to breathe isn't instantly calamitous. Of course, there is no more food coming in, but the body's containment machinery, built into the gut wall, rapidly fails. Suddenly, the food upon which the gut microbiome subsists becomes the gut itself.

There is no way to put this delicately. The gut microbiome dissolves the gut wall and goes on to consume the corpse. The first visible sign of this is a greenish tinge appearing in the lower right quadrant of the abdomen. There are bound to be winners and losers in the microbiological rout. In particular, the obligate anaerobes will perish as the body wall loses integrity and grows permeable to oxygen.

"There is no way to put this delicately. The gut microbiome dissolves the gut wall and goes on to consume the corpse"

Entropy will triumph. Bacteria that were beneficial food processors, such as butyric-acid fermenters, will give way to the catabolic wrecking crew that smashes anything breakable into carbon dioxide, water and ammonia. So (as Kurt Vonnegut said) it goes.

John Wilkinson
Via email
It all depends what happens to your body. If you are cremated, your microbiome goes up in smoke along with you. If you are buried in the cold, cold earth, then it pretty much shuts down. But if you lie in a moderate temperature, it eats you. It's called decomposition!

Red or blue pill

Is there any scientific evidence disproving the notion we are part of a vast simulation run by an advanced civilisation? (continued)

Sam Edge
Ringwood, Hampshire, UK
The arguments against the universe being a simulation due to its complexity in previous answers overlook one obvious possibility. Perhaps the universe is a simulation containing just enough detail to support its single simulated inhabitant – the person who asked the original Last Word question. This would only require a virtual world convincing from a single viewpoint. All our answers would then be part of that simulation without any of us actually existing even in the virtual world.

Answers

Quick quiz #282
Answers

1 Khafre

2 Nyctinasty

3 Five

4 Neil Armstrong

5 1898

Cryptic crossword #151: Collider
Answers

ACROSS 1 Septum, **5** Guilds, **9** Stupor, **10** Score, **11** Reins, **13** Arisen, **14** Issuance, **17** Ents, **18** Promote, **21** Serener, **22** Inertia, **27** Tree rat, **28** Pity, **29** La mancha, **30** Clothe, **31** Enjoy, **32** Lochs, **33** Limpid, **34** Enamel, **35** Vulcan

DOWN 1 Stripe, **2** Prisoner, **3** Ups, **4** Mounts, **5** Grace, **6** Icicle, **7** Fretted, **8** Sensor, **12** Pump, **15** Amstel, **16** Cornea, **19** Anarchic, **20** Epsilon, **22** Impale, **23** Rhythm, **24** Armpit, **25** Venn, **26** Crayon, **27** T-cell, **31** Emu

For each collision pair, take the letter in between. For example, for A/C, enter the letter B.

Answer: BOSON BUDDIES

Happy now?

Assuming you are reading this issue promptly, it's the post-Christmas lull: the weird interregnum between Christmas and the New Year when nobody is quite sure what to do with themselves (unless they are keen shoppers, in which case the January sales have you covered).

Anyway, Feedback recently learned something new about Christmas. This snippet came courtesy of freelance writer Michael Marshall, who wrote a story about a study of whether children behave better in the run-up to Christmas. If you didn't read it, the short answer is "no, they don't". Parents, feel free to take a moment to grieve that one of your best levers to get the little blighters to behave apparently does literally nothing. We will add that the data did suggest that some types of behaviour improved if children were exposed to a lot of Christmas rituals, like putting up a tree and going carolling, and that these rituals might act as a kind of social glue encouraging kids to be kind and cooperative. Maybe try doing more of that? But we wouldn't count on a miraculous transformation.

That wasn't the new thing, though. Michael, we understand, had to leave something out of the story for lack of space. So, since we're in the post-Christmas period, let's have some leftovers.

The study found that parents became more stressed as Christmas approached. In the run-up, they were often worried that it would be a disaster, that key presents wouldn't turn up or that Great-uncle Ted would get drunk and say some slurs at the dinner table. This got worse in the week of Christmas, perhaps because they were working so hard preparing that they couldn't relax and enjoy themselves.

Apparently, it's common for people to only see major rituals as positive experiences once they're over. It's certainly true of weddings, which people describe as the happiest day of their lives when they look back, but if you ask them on the day, they will say they are so nervous they feel like throwing up. Feedback and Mrs Feedback can both attest that, yes, that's what their wedding day was like (Feedback was fortified by a bacon-and-egg sandwich eaten in the bath and a stiff whisky).

It's a curiously human thing to do something that you absolutely hate in the run-up and while it's happening, and subsequently declare it the best thing you ever did. Feedback is not sure what to make of this, but this morning we noticed Feedback's Felines sleeping peacefully in warm spots around the house, and we thought they might possibly be smarter than us.

Twisteddoodles *for New Scientist*

Got a story for Feedback?
Send it to feedback@newscientist.com
or New Scientist, 9 Derry Street, London, W8 5HY
Consideration of items sent in the post will be delayed

Fake fake syndrome

Speaking of not being very smart, Feedback is launching a new recurring segment. We're calling it "generative AIs say the stupidest things". We suspect it will be a bottomless well of material, on a par with nominative determinism, and we hereby invite reader submissions to the usual address.

To kick things off, the anonymous neuroscience blogger Neuroskeptic recently saw something odd in the "AI Overview" that now appears at the top of Google Search. For readers unfamiliar with Neuroskeptic, they have written about the limits of functional brain imaging – especially when it's wildly overinterpreted as "revealing people's thoughts" – and about bad scientific publishing practices.

Neuroskeptic was surprised to see an AI Overview describing "kyloren syndrome": "a disease caused by mutations in mitochondrial DNA" that is "often passed down from a force-sensitive woman to her children". This is immediately and obviously nonsense: Kylo Ren is the baddie in the *Star Wars* sequel trilogy, and "force-sensitive" people only exist in the fictional *Star Wars* universe.

But it's actually worse than that. Neuroskeptic invented kyloren syndrome in 2017, as part of a sting to expose predatory scientific journals that don't properly review studies. They wrote an entire fake paper filled with *Star Wars* references, attributed to Lucas McGeorge and Annette Kin, and submitted it to nine journals. Three of them published it – and another accepted it but didn't publish because Neuroskeptic refused to pay a $360 fee.

Apparently Google's generative AI has not fully grasped the concept of "context".

Swiftquakes

Feedback is sad to see the end of Taylor Swift's world-spanning Eras tour. This is partly because we didn't get to go, because we failed to use our understanding of probability and only registered interest in one concert – severely limiting our chances of getting to the top of the ballot. Maybe Feedback isn't as clever as a generative AI.

But also, the concerts have been so huge that they have produced detectable seismic events. In June, geophysicists at University College London installed nine seismometers near Wembley Stadium in London and recorded the ensuing tremors. *Love Story* produced the biggest earthquake, although, to be clear, it was a magnitude 0.8, so really quite small, followed, appropriately enough, by *Shake It Off*.

Now that Taylor has gone home to (presumably) work on another surprise album, Feedback looks forward to earth movements triggered by other tours. We can't help but suspect that the upcoming Oasis reunion tour might be worth a seismometer or two – if only to detect the precise moment when Liam Gallagher loses his temper and stomps offstage never to return.

Discovery Tours
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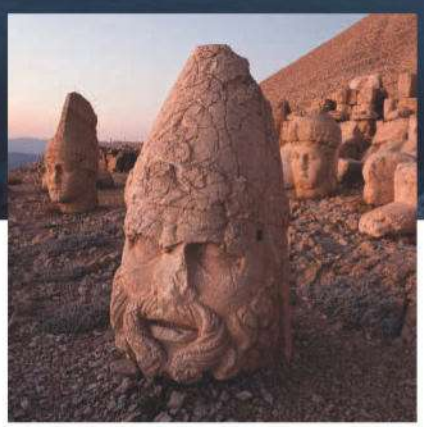


Megalithic Malta: Temples, architecture and archaeology

24 March 2025 | 6 days

Discover the captivating islands of Malta and Gozo, each brimming with extraordinary history and archaeological treasures. These islands are home to a wealth of remarkable sites, from the ancient, enigmatic temples to the impressive fortifications built by the Knights of St. John.

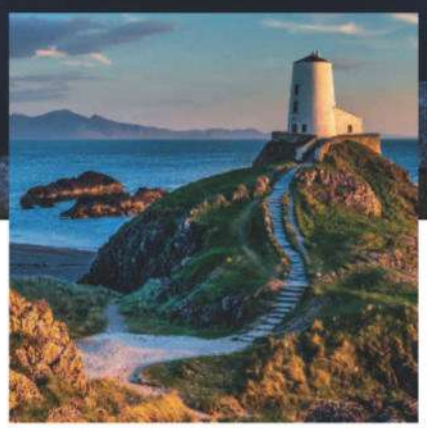
- Visit the megalithic temple complexes of Tarxien, Hagar Qim and Mnajdra, which date back to around 3600 BC
- Explore the Għar Dalam Neolithic cave featuring paintings and ancient remains
- Experience the stunning fortified cities of Valletta, Mdina and Victoria
- Discover Ġgantija, the second oldest human-built freestanding structure in the world
- Enjoy talks and walking seminars from award-winning journalist Juliet Rix

The science of the Renaissance: Italy

7 April 2025 | 6 days

Encounter the great scientific minds and discoveries of the Renaissance, which helped cement Italy's role at the forefront of scientific endeavour – from Brunelleschi and Botticelli to polymaths like Leonardo da Vinci and Galileo Galilei.

- Learn fascinating stories about polymaths, renaissance scientists and artists
- Visit the European Gravitational Observatory to see the Virgo interferometer, which is designed to detect gravitational waves and is the only one of its kind in Europe
- Stay in the beautiful and centrally located 4-star Hotel Degli Orafi in Florence
- Explore the remarkable collections, architecture and churches that showcase the growing knowledge of the era



Retracing Charles Darwin's travels across North Wales

5 May and 1 September 2025
6 days

Explore the dramatic landscapes of Eryri (Snowdonia) National Park and examine the region's geology and how it has been transformed by volcanic and glacial activity over millions of years. Discover the story of Charles Darwin's 1831 and 1842 tours of Wales and retrace his travels on this tour.

- See the spectacular landscapes of north Wales, including the mountains of Snowdonia National Park, the tranquil Llyn Ogwen lake and the rugged coasts of Anglesey
- Discover the evidence that Darwin used to unravel the origin of these landscapes
- Visit the fascinating Parys Mountain, a huge source of copper that has been mined for 4000 years

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